GAS TANKERS

Advanced Course

INTRODUCTION

1 INTRODUCTION

1.1 ABOUT STCW

International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978, as amended, sets qualification standards for masters, officers, and watch going personnel on seagoing merchant ships. STCW was adopted in 1978 by conference at the International Maritime Organization (IMO) in London, and entered into force in 1984. The Convention was significantly amended in 1995. The 133 current state-parties to the Convention represent approximately 98 percent of the world's merchant vessel tonnage.

1.1.1 Limitations discovered

Between 1984 and 1992, significant limitations to the 1978 Convention became apparent. Many people felt that the Convention included vague requirements that were left to the discretion of parties to the Convention. Others felt that there were growing problems with: (a) a lack of clear standards of competence, (b) no IMO oversight of compliance, (c) limited port state control, and (d) inadequacies that did not address modern shipboard functions. Meanwhile, the U.S. deferred ratification efforts and worked for almost a decade to effect necessary changes to our licensing regulations.

1.1.1 Amendments adopted in 1995

On July 7, 1995, a conference of parties to the Convention, meeting at IMO headquarters in London, adopted the package of amendments to STCW. The amendments entered force on February 1, 1997.

1.1.2 Effective dates

The provisions of the Convention not tied to individual mariner certification became effective when the IFR (Interim Final Rule) was published. However, provision was made for certain new requirements to be introduced over a longer period. Full implementation is required by February 1, 2002. For issuance of licenses and documents, the effective dates of the new requirements will be according to transitional guidance published by the STW Subcommittee. Mariners already holding licenses have the option to renew those licenses in accordance with the old rules of the 1978 Convention during the period ending on February 1, 2002. Mariners entering training programs after August 1, 1998 are required to meet the competency standards of the new 1995 Amendments. For persons seeking original licenses, the Coast Guard anticipates that most new training requirements will be incorporated into courses approved by the Coast Guard, or by equivalent courses. To ensure that the competency objectives of the 1995 amendments are met, parties must implement quality assurance programs, with IMO reviewing each parties' national program. Again, this represents a fundamental change in thinking for the international community. It will be mandatory that the "pulse" of the new system be checked on a recurring basis to ensure its "good health."

1.1.3 Familiarization training:

Both the STCW Convention and the U.S. implementing regulations use the term familiarization training or similar terminology five different ways:

a. Companies are required to ensure that seafarers who are newly assigned to a ship are familiarized with their specific duties and with all ship arrangements, installations, equipment, procedures and ship characteristics that are relevant to their routine or emergency duties. Written instructions are to be issued by the company to each ship to ensure this ship-specific familiarization takes place.

b. All persons who are employed or engaged on a seagoing ship other than passengers are required to receive approved familiarization training in personal survival techniques or receive sufficient information and instruction to be able to take care of themselves and take proper action when an emergency condition develops. This includes locating and donning a lifejacket, knowing what to do if a person falls overboard, and closing watertight doors.

c. Officers and ratings who are assigned specific duties and responsibilities related to cargo or cargo equipment on tankers must complete an approved tanker familiarization course if they have not had a minimum period of seagoing service on tankers.

d. Masters, officers and other personnel who are assigned specific duties and responsibilities on board ro-ro passenger ships must complete familiarization training which covers subjects such as operational limitations of ro-ro ships, procedures for opening and closing hull openings, stability, and emergency procedures.

e. Masters, officers and other personnel who are assigned specific duties and responsibilities on board passenger ships other than ro-ro passenger ships must complete familiarization training which covers operational limitations of passenger ships.

1.2 THE COURSE

- ⇨ The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW 78/95), which contains mandatory minimum requirements for training and qualifications of ***masters, officers and ratings*** of chemical tankers.

- ⇨ This training is divided into two parts:

- ⇨ Level 1: Chemical tanker familiarization - a basic safety training course ***for officers and ratings*** who are to have specific duties and responsibilities relating to cargo and cargo equipment

Level 1 training can also be covered through an appropriate period of supervised shipboard service where an approved shipboard training programme is conducted by qualified personnel

⇨ ⇨ Level 2: Advanced training programme on liquefied gas tanker operations. An advanced training programme for ***masters, officers and others*** who are to have immediate responsibilities for cargo handling and cargo equipment.
In addition to level 2 training, such personnel must have completed level 1 and have relevant experience on liquefied gas tankers before signing on to these positions on board

⇨ ⇨ This course covers the requirements for level 1 and level 2 training required by STCW 95 Chapter V Regulation V/1 - 1.2, 2.2 and Section A-V/1 regulations 15 - 21

02. Actual Gas Cargoes

2 ACTUAL GAS CARGOES

In the late 1920th transportation of liquefied gases in bulk started. In the very beginning it was transportation of propane and butane in fully pressurised tanks. When the steel quality became better and the knowledge about propane and butane was better they started to carry those liquefied gases under temperature control. From the mid-1960th we have carried fully refrigerated liquefied gases and now the biggest gas carriers are more than 125 000 m^3.
Liquefied gas is divided into different groups based on boiling point, chemical bindings, toxicity and flammability. The different groups of gases have led to different types of gas carriers and cargo containment system for gas carriers.

- **IMO divides liquefied gases into the following groups:**
- **LPG - Liquefied Petroleum Gas**
- **LNG - Liquefied Natural Gas**
- **LEG - Liquefied Ethylene Gas**
- **NH_3 - Ammonia**
- **Cl_2 - Chlorine**
- **Chemical gases**

The IMO gas carrier code define liquefied gases as gases with vapour pressure higher than 2,8 bar with temperature of 37,8^{o}C.
IMO gas code chapter 19 defines which products that are liquefied gases and have to be transported with gas carriers. Some products have vapour pressure less than 2,8 bar at 37,8^{o}C, but are defined as liquefied gases and have to be transported according to chapter 19 in IMO gas code. Propylene oxide and ethylene oxides are defined as liquefied gases. Ethylene oxide has a vapour pressure at 37,8^{o}C on 2,7 bar. To control temperature on ethylene oxide we must utilise indirect cargo cooling plants.
Products not calculated as condensed gas, but still must be transported on gas carriers, are specified in IMO's gas code and IMO's chemical code. The reason for transportation of non-condensed gases on gas carriers is that the products must have temperature control during transport because reactions from too high temperature can occur.
Condensed gases are transported on gas carriers either by atmospheric pressure (fully cooled) less than 0,7 bars, intermediate pressure (temperature controlled) 0,5 bars to 11 bars, or by full pressure (surrounding temperature) larger than 11 bars. It is the strength and construction of the cargo tank that is conclusive to what over pressure the gas can be transported.

Examples of some gas pressure at 37,8°C and boiling point at atmospheric pressure:

Condensed gas	Gas pressure at 37,8°C bars absolute	Boiling point at atmospheric pressure in °C
Methane CH_4	Gas	- 161
Propane C_3H_8	12,9	- 43
n - Butane C_4H_{10}	3,6	- 0,5
Ammonia NH_3	14,7	- 33
Vinyl Chloride C_2H_3Cl	5,7	- 14
Butadiene C_4H_6	4,0	- 5
Ethylene oxide C_2H_4O	2,7	10,7

2.1 LPG

LPG - Liquefied Petroleum Gas is a definition of gases produced by wet gas or raw oil. The LPG gases are taken out of the raw oil during refining, or from natural gas separation. LPG gases are defined as propane, butane and a mixture of these. Large atmospheric pressure gas carriers carry most of the LPG transported at sea. However, some LPG is transported with intermediate pressure gas carriers. Fully pressurised gas carriers mainly handle coastal trade. LPG can be cooled with water, and most LPG carriers have direct cargo cooling plants that condenses the gas against water.
The sea transport of LPG is mainly from The Persian Gulf to Japan and Korea. It is also from the north- west Europe to USA, and from the western Mediterranean to USA and Northwest Europe.
LPG is utilised for energy purposes and in the petro-chemical industry

2.2 LNG

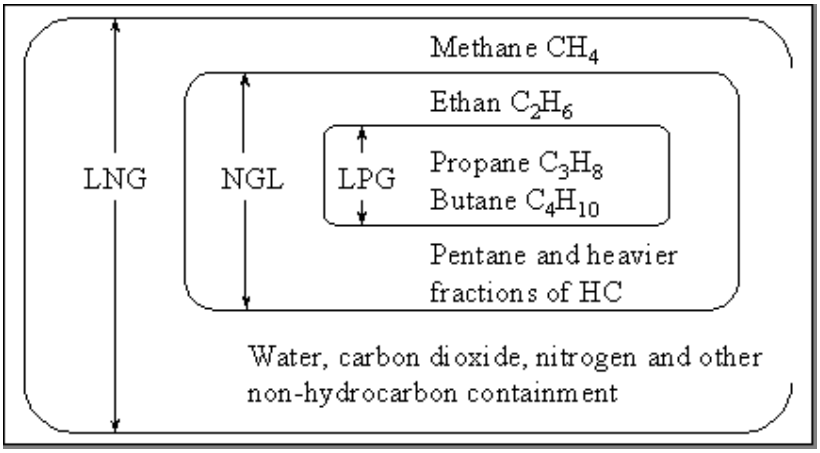
LNG - Liquefied Natural Gas is a gas that is naturally in the earth. Mainly LNG contains Methane, but also contains Ethane, Propane, Butane etc. About 95% of all LNG are transported in pipelines from the gas fields to shore, for example, gas pipes from the oil fields in the North Sea and down to Italy and Spain. Gas carriers transport the remaining 5%. When LNG is transported on gas carriers, the ROB and boil off from the cargo is utilised as fuel for propulsion of the vessel. Cargo cooling plants for large LNG carriers are very large and expensive, and they will use a lot of energy. Small LNG carriers have cargo-cooling plants, and can also be utilised for LPG transportation.

The sea transport of LNG is from the Persian Gulf and Indonesia to Japan, Korea and from the Mediterranean to Northwest Europe and the East Coast of USA and from Alaska to the Far East.
LNG is used for energy purposes and in the petro-chemical industry.

2.3 NGL

NGL - Natural Gas Liquid or wet gas is dissolved gas that exists in raw oil. The gas separates by refining raw oil. The composition of wet gas varies from oil field to oil filed. The wet gas consists of Ethane, LPG, Pentane and heavier fractions of hydrocarbons or a mixture of these. Atmospheric pressure gas carriers and semi-pressurised gas carriers carry the most of the wet gas.
Ethane can only be transported by semi-pressurised gas carriers, which have direct cascade cooling plants and are allowed to carry cargo down to –104°C. This is because Ethane has a boiling point at atmospheric pressure of –89°C. This will create too high condense pressure if using water as cooling medium. The cargo is condensed against Freon R22 or another cooling medium with boiling point at atmospheric pressure lower than –20°C.
Wet gas is transported from the Persian Gulf to the East, Europe to USA and some within Europe. There is also some transport of wet gas in the Caribbean to South America.
NGL is utilised for energy purposes and in the petro-chemical industry.

2.4 COMPOSITION OF NATURAL GAS



2.5 LEG

LEG - Liquefied Ethylene Gas. This gas is not a natural product, but is produced by cracked wet gas, such as, Ethane, Propane, and Butane or from Naphtha. Ethylene has a boiling point at atmospheric pressure of -103,8°C, and therefore has be transported in gas carriers equipped with cargo compartment that can bear such a

low temperature. Cascade plants are used to condense Ethylene. As critical temperature of Ethylene is 9,7°C one can not utilise water to condense Ethylene. The definition of Ethylene tankers is LPG/LEG carrier.
Ethylene is very flammable and has a flammable limit from 2,5% to 34% by volume mixed with air. There are stringent demands regarding the oxygen content in Ethylene. The volume of ethylene must be less than 2% in the gas mixture to keep the mixture below the LEL "lower explosion limit". Normally, there are demands for less than 0,2% oxygen in the gas mixture in order to prevent pollution of the cargo.
Ethylene is utilised as raw material for plastic and synthetic fibres.
Ethylene is transported from the Persian Gulf to the East, the Mediterranean to the East and Europe, the Caribbean to South America. There is also transport of Ethylene between the countries Malaysia, Indonesia and Korea

2.6 AMMONIA NH_3

The next gas we will focus on is Ammonia, which is produced by combustion of hydrogen and nitrogen under large pressure. Ammonia is a poisonous and irritating gas, it has TLV of 25 ppm and the odour threshold is on 20 ppm. It responds to water and there are special rules for vessels that transport Ammonia. We can locate the rules in the IMO Gas Code, chapters 14, 17 and 19.
When ammonia gas is mixed with water, a decreased pressure is formed by 1 volume part water absorbing 200 volume parts ammonia vapour. A decreased tank pressure will occur if there is water in the tank when commence loading ammonia and the tank hatch is closed. With an open hatch, we can replace the volume, originally taken up by the ammonia gas, with air.
One must not mix ammonia with alloys: copper, aluminium, zinc, nor galvanised surfaces. Inert gas that contains carbon dioxide must not be used to purge ammonia, as these results in an carbamate formation with the ammonia. Ammonium carbamate is a powder and can blockage lines, valves and other equipment.
The boiling point for ammonia at atmospheric pressure is –33oC, and must be transported at a temperature colder than –20oC. One can cool ammonia with all types of cargo cooling plants. Ammonia is transported with atmospheric pressure gas carriers or semi-pressurised gas carriers. Gas carriers carrying Ammonia must be constructed and certified in accordance with IMO's IGC code for transportation of liquefied gases. The definition for ammonia tanker is LPG/NH, carrier.
Ammonia is utilised as raw material for the fertiliser industry, plastic, explosives, colours and detergents.
There is a lot of transportation from the Black Sea to USA, from USA to South Africa and from Venezuela to Chile.

2.7 CHLORINE CI2

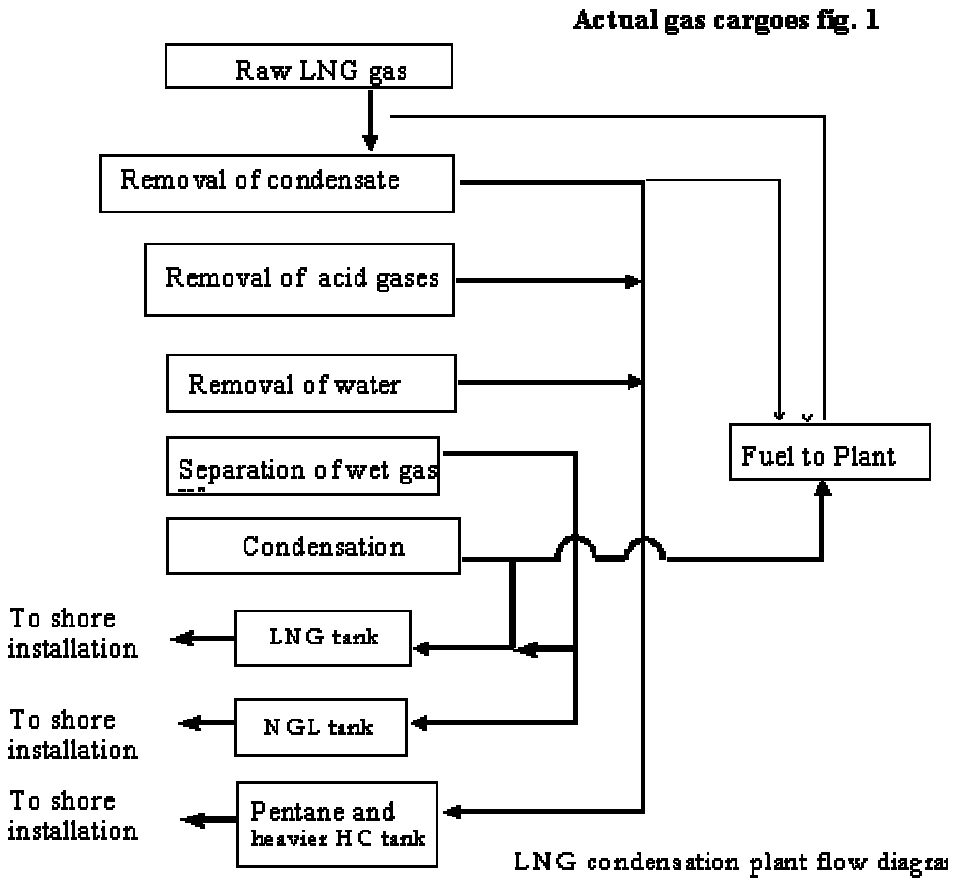
Chlorine is a very toxic gas that can be produced by the dissolution of sodium chloride in electrolysis. Because of the toxicity of Chlorine it is therefore transported in small quantities, and must not be transported in a larger quantity than 1200m^3. The gas carrier carrying chlorine must be type 1G with independent type C tanks. That means the cargo tank must, at the least, lie B/5 "Breadth/5" up to 11,5 meter

from the ships side. To transport Chlorine, the requirements of IMO IGC code, chapters 14, 17 and 19 must be fulfilled. Cooling of Chlorine requires indirect cargo cooling plants.
The difference of Chlorine and other gases transported is that Chlorine is not flammable.
Chlorine is utilised in producing chemicals and as bleaching agent in the cellulose industry.

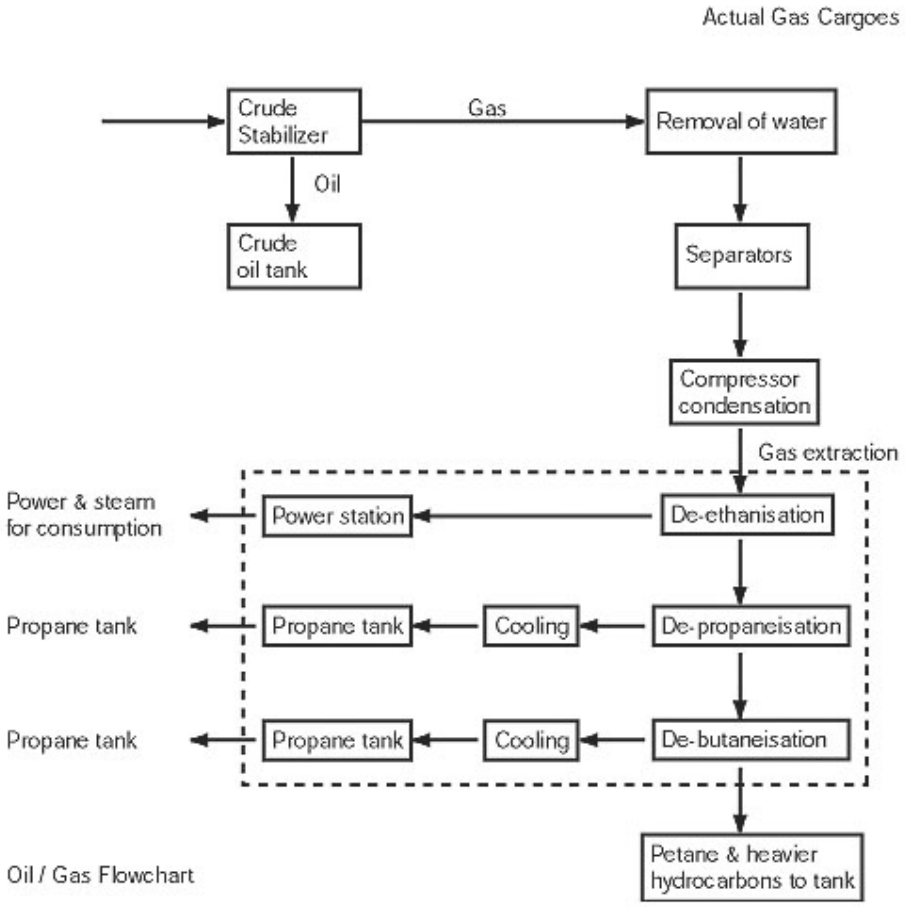
2.8 CHEMICAL GASES

The chemical gases mentioned here are the gases produced chemically and are defined in IMO's rules as condensed gases. Because of the gases' boiling point at atmospheric pressure and special requirements for temperature control, these gases must be carried on gas carriers as specified by the IMO gas code. Condensed gases are liquids with a vapour pressure above 2,8 bars at 37,8^{o}C. Chemical gases that are mostly transported are Ethylene, Propylene, butadiene and VCM. Chemical gases that have to be transported by gas carriers are those mentioned in chapter 19 in IMO IGC code. There are, at all times, stringent demands for low oxygen content in the cargo tank atmosphere, often below 0,2% by volume. This involves that we have to use nitrogen to purge out air from the cargo compartment before loading those products.
In addition, even though the vapour pressure does not exceed 2,8 bars at 37,8^{o}C such as, ethylene oxide and propylene oxide or a mixture of these, they are still in the IMO gas code as condensed gases. Gas carriers that are allowed to transport ethylene oxide or propylene oxide must be specially certified for this. Ethylene oxide and propylene oxide have a boiling point at atmospheric pressure of respectively 11^{o}C and 34^{o}C and are therefore difficult to transport on tankers without indirect cargo cooling plants. Ethylene oxide and propylene oxide can not be exposed to high temperature and can therefore not be compressed in a direct cargo cooling plant. Ethylene oxide must be transported on gas tanker type 1G.
Chemical gases like propylene, butadiene and VCM are transported with medium-sized atmospheric pressure tankers from 12000 m^3 to 56000 m^3. Semi-pressurised gas carriers are also used in chemical gas trade and then in smaller quantity as from 2500 m^3 to 15000 m^3.
Chemical gases are transported all over the world, and especially to the Far East where there is a large growth in the petro-chemical industry. Chemical gases are mainly utilised in the petro-chemical industry and rubber production.

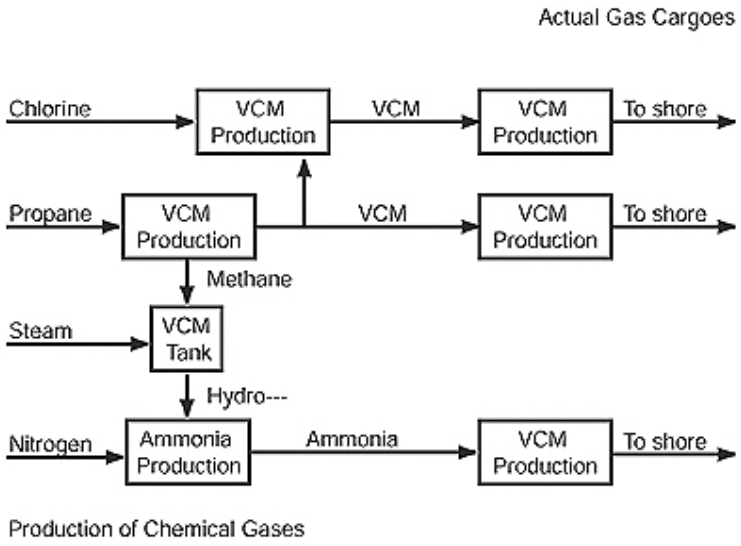
2.9 LNG CONDSATION PLANT FLOW DIAGRAM



2.10 OIL/GAS FLOW DIAGRAM



2.11 PRODUCTION OF CHEMICAL GASES



Production of Chemical Gases

2.12 CONNECTION TABLE

Table showing connection between cargo temperature and type of compartment and secondary barrier requirement

Cargo temperature at atmospheric pressure	**- 10°C and above**	**Below -10°C down to –55°C**	**Below -55°C**
Basic tank type	No secondary barrier required	Hull may act as secondary barrier	Separate secondary barrier where required
Intergral		Tank type not normally allowed	
Membrane		Complete secondary barrier	
Semi-membrane		Complete secondary barrier	
Independent			
Type A		Complete secondary barrier	
Type B		Partial secondary barrier	
Type C		No secondary barrier required	
Internal insulation			
Type 1		Complete secondary barrier	
Type 2		Complete secondary barrier is incorporated	

03- Cargo Compartment Systems

3 CARGO COMPARTMENT SYSTEMS

Cargo compartment systems on gas carriers are divided into groups and types. The group division indicates how the cargo tanks transfer dynamic strength to the vessel hull. Cargo tanks that will be used on gas carriers must at all times have a documented strength and certification of welded joints and steel quality. The cargo tanks on gas carriers are rarely a direct part of the hull, but rather tanks installed into the hull and isolated from the hull.
Gas carriers are built with two or more spaces where the cargo tanks are installed. The space where the cargo tank is installed is called **hold space.** How much hold space volume the cargo tank absorbs depends on the cargo tank's shape. Cargo tanks isolated from the hull, for example, cylinder tanks, must be electrically grounded with a wire or steel strip to the hull.

Table showing connection between cargo temperature and type of compartment and secondary barrier requirement

Cargo temperature at atmospheric pressure	- 10°C and above	Below -10°C down to –55oC	Below -55°C
Basic tank type	No secondary barrier required	Hull may act as secondary barrier	Separate secondary barrier where required

Integral		Tank type not normally allowed
Membrane		Complete secondary barrier
Semi-membrane		Complete secondary barrier
Independent		
Type A		Complete secondary barrier
Type B		Partial secondary barrier
Type C		No secondary barrier required
Internal insulation		
Type 1		Complete secondary barrier
Type 2		Complete secondary barrier is incorporated

Cargo tanks that are built for fully refrigerated gas carriers, and tanks with MARVS less than 0,7 bars, must at all times have full or partly secondary barrier. Secondary barrier is a tank or hull construction built outside the cargo tank itself, either in the insulation between cargo tank and hull, or in the hull around the cargo tank. If the hull around the cargo tank is used, it will be the ballast tank, ships side or cofferdams that is the secondary barrier. When utilising the hull around the cargo tank as the secondary barrier the vessel is limited as it will not have the capability to transport cargo colder than –55°C.

Secondary barrier will prevent cargo liquid from any possible leaks coming from the cargo tank cooling the environment around the cargo tank, for example the ship sides. The secondary barrier must have a construction that, at a minimum, keeps the cargo liquid away from the surroundings for at least 15 days and maintains its full function at static lurch of 30^{o}.
All cargo tanks on gas carriers are constructed to a given excess pressure and vacuum. The safety valve's maximum allowed set point, called **MARVS,** is stated in accordance to specification and pressure test, stated by the manufacturer of the cargo tank. The tolerance of vacuum on the cargo tanks is stated in bars, kg/cm^2 or percentage of vacuum. MARVS and vacuum for each cargo tank must be specified in the vessels "Certificate of Fitness".
US Coast Guard has more stringent rules for safety margins for pressure tanks than IMO, this indicates that cargo compartment on gas carriers have different MARVS pressures for IMO and USCG.
In hold spaces and inter barrier spaces there are demands for an own bilge system that is independent from the vessel's other bilge systems. This is arranged with independent ejectors or bilge pumps in the spaces and usually one in each side of the space. Inter barrier space is the space between the cargo tank and the secondary barrier.
The bilge arrangement is meant to pump out the cargo if there has been a leakage from the cargo tank. The system can also be utilised to remove water from the hold space or inter barrier space if there is accumulation of condensed water. If we have to pump water we must be sure that all connections to the loading system is disconnected.
On atmospheric pressure tankers, hold space and inter barrier space must at all times have a neutral atmosphere, either by dry inert or nitrogen when loaded with flammable cargo.
Nitrogen or dry air must be utilised when the cargo content is Ammonia or non-flammable cargo. When the cargo is Ammonia one must under no circumstance utilise inert containing CO_2 in the spaces, because Ammonia has a reaction on CO_2 and form a material called Ammonium Carbamate

IMO divides the cargo tanks into 4 main groups:

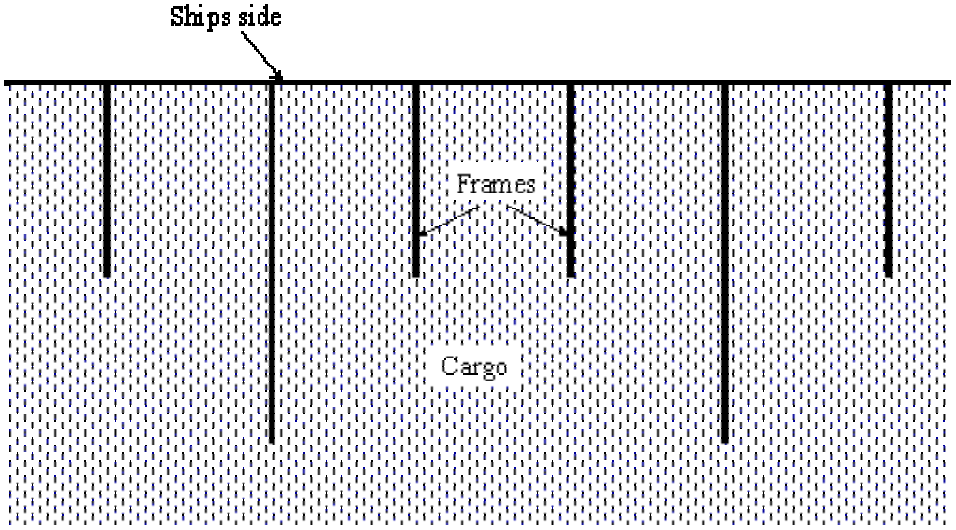
- **Integrated tanks**
- **Membrane tanks**
- **Semi - Membrane tanks**
- **Independent tanks, type A, B, and C**
-

The characteristics of integrated, membrane and semi membrane tanks is that they all transfer static stress in the form of tank pressure to the hull around the cargo tank when this is loaded. Independent tanks only transfer the weight of the cargo tank and the cargo to the hull fundamentals, but does not transfer static pressure.

3.1 INTEGRATED TANKS

The first cargo compartment system we will look at is **integrated cargo tanks**. It is the same type of cargo compartment that we have on oil tankers, OBO carriers and product tankers. The cargo tank is an integrated part of the hull so the hull absorbs the weight and pressure from the cargo. This type of cargo compartment is less suited and rarely approved for gas transportation. If we transport cargo colder than $-10^{o}C$, this type of cargo compartment is not approved. Then low temperature steel in the cargo compartment is required. International rules also require a minimum distance from the ship's side to the cargo tank of 760 mm for guiding of toxic or flammable cargo. This prevents pollution from collision or run grounding.

Example of integral tank



3.2 MEMBRANE TANKS

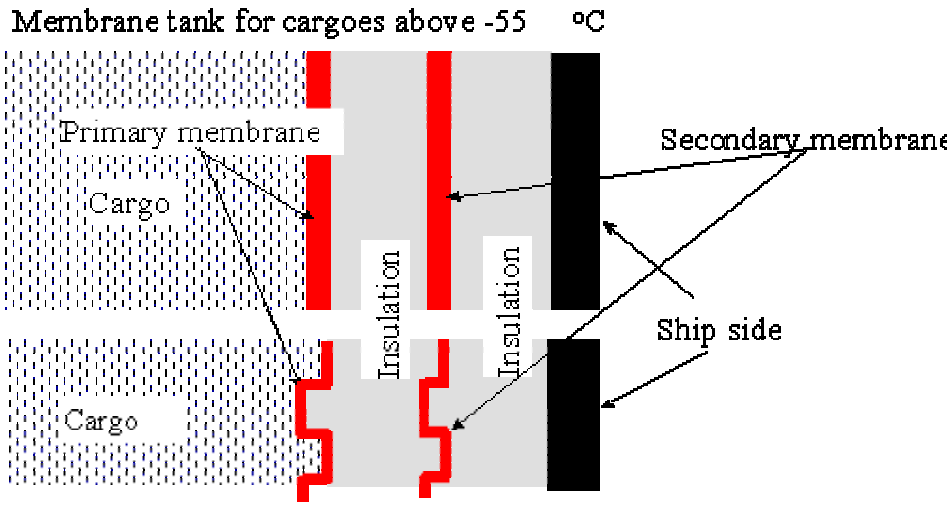
Membrane compartment are divided into two groups, membrane tank system and semi- membrane tank system. Membrane tank system is built up with two equal membranes, while semi-membrane system have a membrane against the cargo and metal or veneer as secondary barrier. Common for all membrane tanks is that there is no centre bulkhead for reducing the free liquid surface, but is built up with a trunk for narrowing the tanks up against the top of the tank.

3.2.1 Membrane tank system

Membrane tank is a cargo tank built of thin plate of invar steel, stainless steel or ferro nickel steel with a content of 36% nickel. Characteristic for these types of steel is a very small thermal expansion coefficient approximate equal 0. The tank shell and the secondary barrier are built in profiles formed as a membrane; this renders the material thickness small and no more than 10 mm thick. The membrane thickness is normally of 0,5 to 1,2 mm. There is insulation between the secondary membrane and the hull. The insulation is often perlite filled in plywood boxes, placed outside each other like building blocks, or polyurethane gradually sprayed directly on as the tank is built up. The hull takes up all weight from the cargo, and the membrane

takes up the thermal expansion. Normal excess pressure for such cargo tanks is 0,25 bars, and there are demands for secondary barrier.
We can utilise the hull as secondary barrier for cargo temperatures down to –55°C, but we must utilise low temperature steel in the hull round the cargo tank. Frequently ballast tanks or cofferdams form the hull structure around the cargo tank. For cargo colder than –55°C a tank must be placed into the insulation as secondary barrier. French Gaz-Transport patent utilise two identical membranes outside each other as primary and secondary barriers, with 36% nickel steel or invar steel. The insulation in Gaz-Transport patent is perlite filled with plywood boxes.
Technigaz membrane system utilises stainless steel in the main membrane and veneer in the secondary membrane. The main membrane is welded together of small plates by a special shaping so that the tank tolerates expansion, the plate thickness is about 1,2 mm. The first tanks from Technigaz utilized veneer plates, as secondary barrier and balsa as insulation. Polyester-coated aluminium foil is now utilised as secondary barrier, and polyurethane foam for insulation. These tank types are utilised on large LNG and LPG tankers.

3.2.2 Sketch on membrane tank

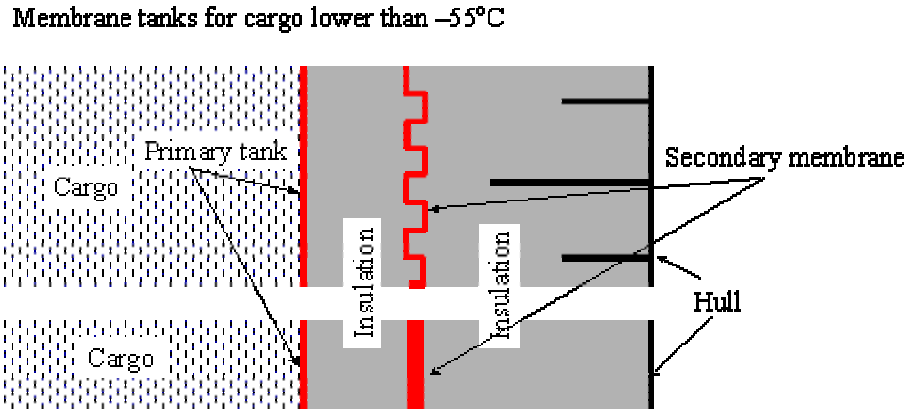


3.3 SEMI - MEMBRANE TANKS

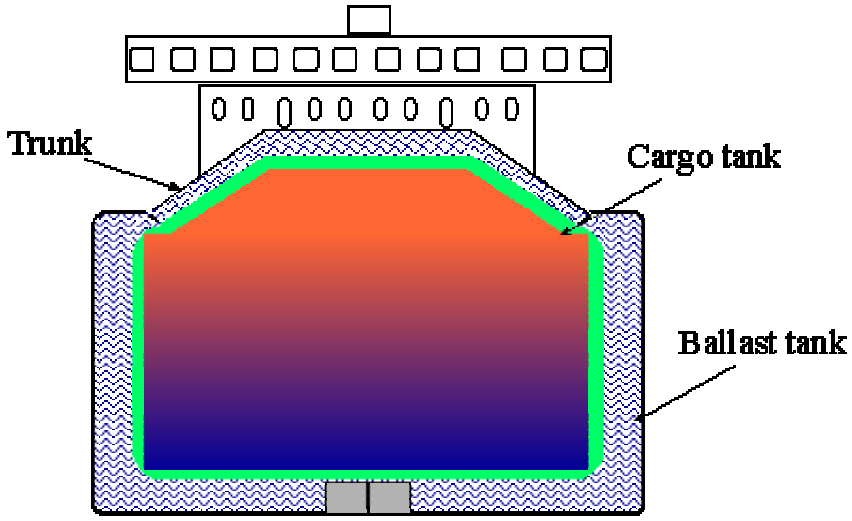
These are tanks used on large LPG tankers. **Semi-membrane tanks** are built up with an inner tank, insulation, membrane and insulation against hull. It is the membrane that takes up the thermal expansion. The tanks are built of aluminium, ferro nickel steel with 36% nickel, or built of stainless steel. The insulation is mostly perlite, but can also be polyurethane or polystyrene. The hull absorbs all dynamic loads from the cargo tank when the tank is loaded. Normal excess pressure for such cargo tanks is 0,25 bars, and there is a demand for secondary barrier.
One can use the hull as secondary barrier for cargo temperature down to –55°C, but one must utilise low temperature steel in the hull around the cargo tank. One can also place a tank into the insulation as secondary barrier. One cannot utilise the hull as secondary barrier for temperature colder than –55°C. A membrane inside is then

built in the insulation as secondary barrier. This tank type was designed for LPG transportation, but no LPG tankers are built with this tank type. In recent years, Japanese yards have started to utilise this tank type on large LPG tankers.

3.3.1 Example of semi-membrane tank



3.3.2 Cross-section of gas tanker with membrane tank



3.3 INDEPENDENT TANKS

Independent cargo compartment is cargo tanks that do not transfer the pressure loads to the hull when they are loaded. Therefore, only the tank weight is transferred to the cradles or the support points in the hull. The cargo tanks are built with support to prevent the tank from slipping forward, astern, to the side or floating up.
Independent tanks are divided into three types: A, B and C. This division distinguishes between the pressure the tank must tolerate and the demands for secondary barrier. **Independent tank Type A** has the weakest strength of the independent tanks, and there are demands for full secondary barrier. **Independent tank type B** has greater strength than type A does, and only demands a partly

secondary barrier. **Independent tank type C** is a pressure tank with no demands for secondary barrier.

3.4.1 Independent tanks type A

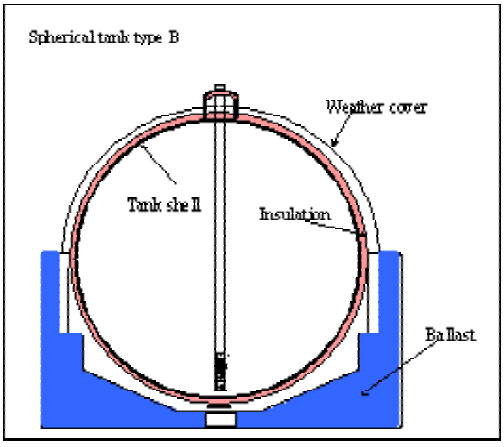
Independent tank type A could be a prismatic tank and built in 3,5% nickel steel, coal manganese steel or aluminium. The material is a recognised standard, steel quality approved by the class companies. This type of cargo tank is utilised for carrying LNG, LPG and ammonium.
This type of tanks is built for excess pressure less than 0,7 bars. Normal operating pressure is 0,25 bars. The cargo tanks are mounted on building blocks so the tank can expand freely. On top of the tanks and in the ship side or up under deck, brackets are welded to prevent the tank from floating up.

3.4.2 Example of "anti float" brackets

A full secondary barrier for this type of tank is required. On LPG tankers designed for minimum temperature of –48°C, the hull is generally used as secondary barrier as low temperature steel is used in the hull construction around the cargo tank. If the hull is not utilised as secondary barrier an extra tank around the main cargo tank are constructed. This is done by building a tank of veneer plates around the cargo tank with **polyurethane foam** as insulation in between. One can also use nitrogen or inert between the tanks as insulation.

3.4.3 Independent tanks type B

Independent tank type B is a **prismatic tank, spherical tank** or membrane tank. These tanks are designed and model tested, and they have better quality than type A tanks. This tank type is used for large LPG and medium-sized tankers.

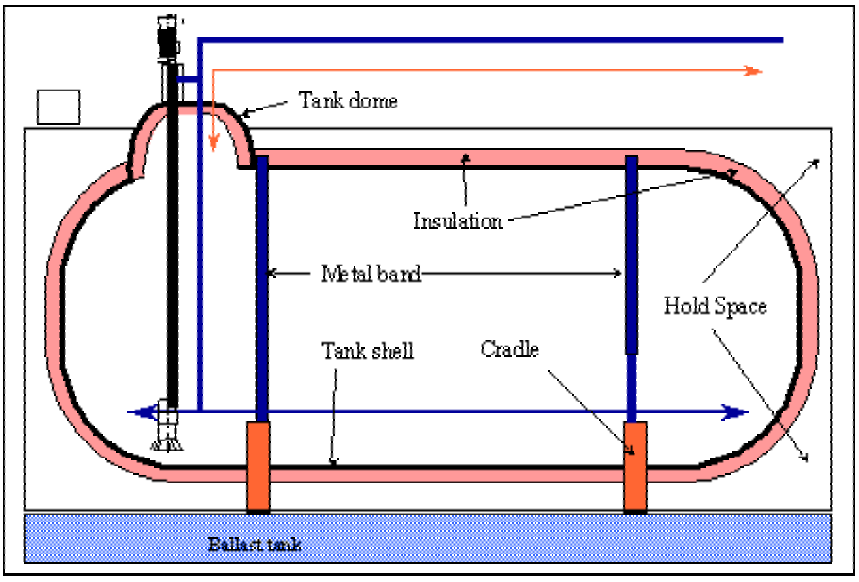


Prismatic tanks are produced in aluminium or 3% nickel steel in stiff plates. The tanks rest on reinforced plywood supports for free expansion. The tanks are normally provided with centreline bulkhead to reduce the free liquid surface. The tanks are insulated with polyurethane or perlite. Submerged pumps or deepwell pumps are utilised as discharging pumps.

Spherical tanks produced by **Moss-Rosenberg** patent are produced in aluminium or 9% nickel steel. The tanks are supported with cargo tank shirt at equator and down to the hull. Around the tank that is above deck there is a waterproof cover. The tanks are equipped with submerged pumps.
Polyurethane is often utilised as foam on type B tanks as insulation; this is sprayed directly on the tank shell. Other types of insulation are polystyrene plates placed in layers, or perlite either filler around the tank or placed in small veneer cases. The insulation on spherical tanks is spinned on from the bottom and up.

3.4.4 Independent tanks type C

Independent tanks, type C are either spherical tanks or cylinder tanks. The tanks are built in carbon manganese steel, 2 – 5 % nickel steel or acid-proof stainless steel. This type of tank has a large rate of security, and therefore does not need secondary barrier. This tank type is utilised for fully pressurised gas carriers and semi-pressurised gas carriers.
Tanks type C utilised on gas carriers are built in sizes from 300 m^3 to 2500 m^3.



Either submerged or deepwell pumps are utilised as discharge pumps.
The tanks are stored on cradles and welded to one of the cradles. The other cradle functions as a support for the tank to expand freely. Some patents keep the tanks down in the cradles by steel bands that are extended over the tank and fastened to the cradle. Another patent is to weld "anti float" brackets on top of the cargo tank and up under deck to prevent the tank from floating up. Tanks designed for cargo colder than –10°C must have insulation. Normally polyurethane or polystyrene is utilised as insulation.
The insulation is either sprayed directly or placed on in blocks on the cargo tank. The thickness of the insulation is dependent of the quality of the insulation material and the temperature of the cargo. The thickness of the insulation on tanks that carry ethylene is about 200 mm.

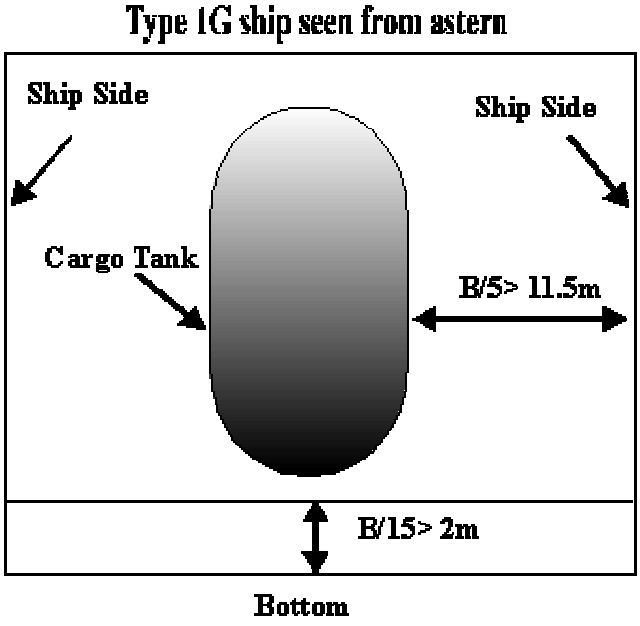
3.5 TYPES OF GAS CARRIERS

Gas carriers are tankers constructed for transporting liquefied gases in bulk. IMO defines liquefied gases as products with a vapour pressure exceeding 2,8 bar absolute at a temperature of 37,8^{o}C. Gas carriers are built according to IMO's Gas Codes. There are three versions of gas codes; the first deals with existing gas carriers and passes for gas carriers delivered before 31st of December 1976. The next code passes for gas carriers delivered on or after 31st of December 1976, but before 1st of July 1986. The third gas code, IGC Code passes for gas carriers started or the keel set after the first of July 1986. The latest gas code is for gas carriers that keel is laid and 1% of the construction mass is used on 1st October 1994.
The gas code has a content in demands for damage stability, gas tankers cargo handling equipment, cargo tanks, steel qualities in cargo tanks, pipe systems for cargo handling, personnel protection, safety valves, etc.
Gas carriers are divided into three main groups and four types. The gas carrier owner decides which group and type the carrier should have, according to the freight the vessel will trade.
The three main groups are:

- **Fully pressurised carriers: designed for excess pressure in the cargo tank above11 bar.**
- **Semi-pressurised carriers: designed for excess pressure the cargo tank on 0,5 – 11 bars, the pressure is normally 3 – 5 bars.**
- **Fully refrigerated carriers: designed for excess pressure in the cargo tank below 0,7 bars, the pressure is normally 0,25 – 0,3 bars.**

Each of the groups is again divided into ship types dependent on the cargo's hazardous properties (i.e.: toxicity, flammability, reactivity etc.). It is the ship owner's specification of the gas carrier, the international rules determined by IMO, national rules and class companies rules that decide to which group and ship type the carrier belongs.
All gas carriers classed according to IMO IGC Code for transportation of gases mentioned in chapter 19, is given one of the following description types: 1G, 2G, 2PG or 3G. Ship type 1G is the type that can carry all cargoes mentioned in chapter 19 of the IGC Code, and has the largest rate of security to avoid pollution of the environment.
Ship type 1G is a gas carrier that can carry all products mentioned in chapter 19 in the IGC Code, and requires largest rate of security to prevent leakage from the product to the surroundings.
Ship type 2G is a gas carrier that can carry the products marked in 2G, 2PG and 3G in chapter 19 in the IGC Code, and that requires defensible security to prevent leakage of the product.
Ship type 2PG is a gas carrier of 150 meters or less that can carry the products marked 2PG or 3G in chapter 19 in the IGC Code, and that requires defensible security to prevent leakage of the product. Also, where the product is transported in independent tanks type C, which are designed for MARVS of at least 7 bars. Then,

the cargo tank system is calculated for temperatures of –55°C or warmer. Gas tankers of 150 meters or more, but with the same specification, as 2PG ships must be calculated as 2G ships.
Ship type 3G is a gas carrier that can carry the products marked 3G in chapter 19 in the IGC Code, and that requires moderate security to prevent leakage of the product. The ship type is reported in column c in chapter 19 in the IGC Code.
The type of gas carrier is specified in the vessels IMO Certificate of Fitness. On the certificate, there is also a product list of which products the vessel can carry. The type description of the gas carrier is given by the year when the keel was laid and the cargo tanks distance from ship side, damage stability, floating capability and of what material the cargo tank is made.
As an example on ship type 1G, the cargo tank must lie at least B/5 parts up to 11,5 meters from the ship side. From the bottom plate and up to the tank no less than 2 meters or B/15 parts. B is equal to the vessel breadth. This type of carrier must tolerate any damage to the ship side along the whole ship's length. All information of the demands made for the different ship types is located in IMO Gas Code, and all gas tankers must have this publication onboard.



3.6 FULLY PRESSURISED CARRIERS

Fully pressurised gas carriers were the first generation of gas carriers that were built to transport liquefied gases in bulk. This type of gas carrier trades mostly where LPG is consumed as energy, such as house heating and cooking etc. The trade area is often limited to near coastal waters. This type of gas carrier is still built, but is built to be more modern with discharging pumps in cargo tanks and indirect cargo cooling plant for more flexible cargo handling. We divide this type of gas carrier into two, one for LPG trade and one for Chlorine trade.

3.6.1 Fully pressurised LPG carriers

This type of gas carrier is the type that in proportion to displacement can carry the lowest weight of cargo, this because it is transported under pressure at the surrounding temperature, "ambient". When the tank pressure increases the cargo's temperature also increases and the density of the liquid will be lower. The cargo tank construction itself is heavy as these are built of common ship steel with a thick tank shell to endure high pressure. There are no requirements for insulation of the cargo tanks because these carriers are not allowed to transport cargoes with temperature colder than $-10^{o}C$.

These gas carriers are built in sizes up to about 3000 m^3, and are built for an excess pressure corresponding to an ambient temperature of $45^{o}C$. Propane has a saturation pressure of 17,18 bars at $50^{o}C$. IMO has a requirement when building fully pressurised tanks that they must be able to bear **ambient** (surroundings temperature) cargo with a temperature on $45^{o}C$. The type of cargo determines the excess pressure for which the tanks must be built. Normally, fully pressurised carriers LPG have a relief valve setting at 18 bars, consequently, they can also carry propylene in tropical waters.

This type of gas carrier is easy to operate, because the cargo does not need to be cooled down on the sea voyage. To prevent vapour into the atmosphere when loading, they can remove the excess vapour by having vapour return to shore. Fully pressurised gas carriers don't need discharge pumps in the cargo tanks, because the excess tank pressure will discharge the liquid to shore. Hot gas from shore can be used to hold the excess pressure in the cargo tank. If there is no utilisation of the discharging pumps while discharging, the cargo tank's excess pressure must at all time be higher than the shore backpressure.

Some fully pressurised gas carriers are equipped with booster pump(s) (auxiliary pump) on deck. This pump is used to discharge against a higher pressure than the excess pressure in the cargo tanks. Booster pump is a one-stage centrifugal pump installed on deck close to the ship manifold. Normally a booster pump manages to increase the pressure up 9 bars. If the cargo tank's pressure is 7 bars, then we can manage 16 bars on the discharge line with the booster pump. We must bear in mind that when running the booster pump against maximum pressure, the flow through the pump is very low. We must always prime the booster pump before starting it, generally by draining the discharge line to the ventilation mast. It is the pressure in the shorelines that determines the manifold's pressure and whether we should use the booster pump or not.

Fully pressurised gas carriers are equipped with a heat exchanger (cargo heater) connected to the loading lines with vales and spool piece (adapter). When the heat exchanger is not in use it is segregated from the liquid line. The heat exchanger is used when we are loading a cargo with temperature below $0^{o}C$, for example, propane at atmospheric pressure corresponding to $–42,8^{o}C$ directly into the vessels cargo tanks. Then the cargo has to be heated to above $–10^{o}C$ before we load it down to the cargo tank.
Fully pressurised gas carriers have a small cargo compressor to produce excess pressure in the cargo tanks or remove over pressure from the cargo tanks. Vapour is sucked from the cargo tanks to the compressor, and hot vapour is returned back to the cargo tanks. These compressors are in general small, and are utilised only for holding the temperature on the cargo.
Fully pressurised gas carriers are constructed with independent tank type C, cylindrical or spherical tanks. These are tanks installed on "cradle-like" supports down in the hold space (the space around the cargo tank), and the ship hull doesn't recover dynamic loads from the cargo tanks.
Actual cargo for fully pressurised carriers is LPG and some chemical gases. The kind of cargo each vessel can carry is stated in the vessel's IMO Certificate of Fitness. Fully pressurised gas carriers are most utilised for carrying of ambient LPG and some chemical gases as propylene, mainly in the Far East, South America, the Caribbean and The Mediterranean.

Advantages:

- **Easy to operate because all discharging takes place without pumps.**
- **Low costs in building because common steel is utilised in the cargo tanks.**
- **Low costs for maintenance, because there is little mechanical utility equipment for cargo handling.**
- **Simple discharging/loading equipment on deck.**
- **No insulation of tanks or liner, no need in maintenance of the insulation, and one can easily inspect the cargo tanks and the lines from the outside.**
- **Transporting the cargo by surrounding temperature (ambient), no cooling of the cargo gives low energy consumption.**

Disadvantages:

- **Small amount of cargo in proportion to displacement as the cargo is transported ambient.**
- **Limited trade area because of dependence of discharging to pressure tanks on shore.**
- **Limited cargo volume because the tankers are not built large than $3000m^3$.**
- **Unable to have cold cargo in the tanks because of the steel quality.**
- **Heavy cargo construction because of toleration of the pressure.**

3.6.2 Fully pressurised chlorine Cl_2 carrier

These tankers are built as fully pressurised tankers LPG, but because of the toxicity of chlorine, special requirements are set on this type of gas carrier. The requirements are stated in the IGC code chapter 14, 17 and19. This type of ship must not have cargo tanks larger than 600 m^3, and total capacity must not exceed 1200 m^3. Consequently, these gas carriers are smaller than the common fully pressurised gas carriers LPG.

The cargo tanks must be built for an excess pressure not lower than 13,5 bars, which is saturation pressure for Chlorine at 45^{o}C. Tanks and lines must be built in steel quality that tolerates a temperature down to –40^{o}C. Cargo lines must at maximum have an inner diameter of 100 mm. Tanks and lines must be insulated. Polyurethane or polystyrene is utilised as insulation. This information is at all times specified in IMO Certificate of Fitness. There is also a summary in the certificate of fitness as to what type of cargoes the actual tanker is allowed to carry.

This type of gas carrier often has an indirect cargo cooling plant with coils welded to the outside of the tank shell. In general ethanol is used as cooling medium against Freon (R22) in a small freon cooling plant. Other indirect cargo cooling plants utilise freon as the cooling medium by directly pumping freon in and around the coils. It is prohibited to use any kind of direct cargo cooling plant on chlorine.

To discharge these type of gas carriers the cargo tanks excess pressure is used. Either the pressure established by dry nitrogen or only the tank pressure is used. Chlorine vapour obtained from shore via the ship's vapour lines can also be used for discharging. Some chlorine carriers are also equipped with submerged pumps in the cargo tanks.

This type of gas carrier mostly stays in the chlorine trade, because of the toxicity of the cargo. There are few cargo owners that accept to load other products after Chlorine. Chlorine carriers can, if they are accepted, also carry LPG and some chemical gases depending on the relief valve's set point.

Because of the toxicity of chlorine it is necessary that the chlorine carriers are equipped with a chlorine absorption plant connected to cargo tanks and cargo lines. The absorption plant must neutralise a minimum 2% of total cargo capacity. The gas detector onboard must measure 1 ppm chlorine and alarm setting at 5 ppm. The gas detector must scan the bottom of hold space, line from safety valve, the outlet from chlorine absorption plant, into ventilation for accommodations and all of the gas area on deck.

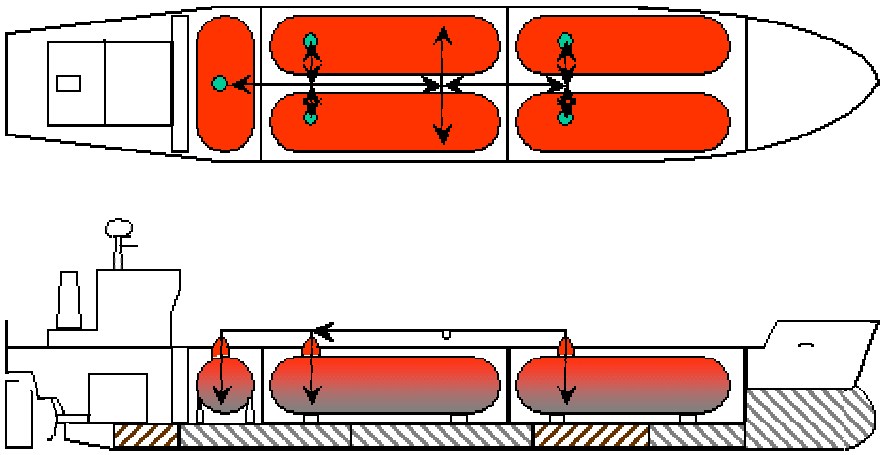
Advantages:

- **They are easy to operate.**
- **Simple cargo handling equipment on deck.**
- **Tanks and lines are insulated.**
- **They have an indirect cooling plant, and are thereby capable to cool cargo.**

Disadvantages:

- **They are small tankers, and have thereby low loading capacity.**
- **Expensive to build in proportion to the cargo amount they can transport.**
- **The tankers are mainly designed for Chlorine.**

Fully pressurised gas



3.7 SEMI PRESSURISED GAS CARRIERS

Semi-Pressurised gas carriers are a development from fully pressurised carriers. Semi-pressurised carriers are equipped with discharging pumps in the cargo tank, cargo cooling plant, heat exchanger (cargo heater) and booster pumps. In addition, the tanks and lines are insulated, normally with polyurethane or polystyrene. This renders the ship type with more flexibility than other gas carrier types. Semi-pressurised tankers are divided in two types - Semi-pressurised carrier LPG/LEG and Semi-pressurised tanker combined gas and chemicals.

3.7.1 Semi-pressurised LPG/ LEG carriers

Semi-pressurised carriers are more complex than fully pressurised carriers due to their extended cargo handling equipment. Semi pressurised tankers are equipped either with direct cargo cooling plant or cascade cargo cooling plant. Which type of cargo cooling system the gas carrier is equipped with depends on the type of cargo it is meant to carry. If the tanker is carrying LPG or Ammonia with a boiling point at atmospheric pressure warmer than –48^{o}C, the choice is generally direct cargo-cooling plant. If the vessel will transport cargo with a boiling point at atmospheric pressure colder than –48^{o}C, the vessel must be equipped with cascade cooling plant.

Before loading cold cargo, the cargo tank steel must be cooled down to approximate 10^{o}C above cargo temperature. It is common that the first 30^{o}C can be cooled the first hour. Thereby we can cool down the shell by 10^{o}C an hour until it is about 10^{o}C above the cargo temperature. The cooling of the tank steel must be done to prevent thermal expansion and crack in the tank shell. A tank of 1000 m^3 that is cooled from 20^{o}C to –103^{o}C shrinks about 5 m^3.

In addition, when the shell is cooled down, the time for loading will be reduced and thereby reduces the time ashore. That will save harbour expenses for the ship owners or the charterer. It is specified in the operating manual for each vessel how to cool down the cargo tank shell. We must be attentive to this, because uneven thermal shrinkage of the cargo tank can lead to damage to the cargo tank.

Semi-pressurised gas carriers are normally built in sizes from 2000 m^3 to 15000 m^3. They are designed to carry cargo with temperatures down to –48^{o}C for LPG and Ammonia, and –104^{o}C for LEG.

Semi-pressurised gas carriers are utilised for transportation of petrochemical gases, such as, Propylene, Butadiene, Ethylene and Ammonia, but also for gases, such as,

Propane, Butane and Ethane. There have been plans to build semi-pressurised tankers up to 36000 m^3, but they are still not built.
Semi-pressurised gas carriers have independent tanks type C either as cylinder or spherical tank designed for tank pressure between 0,5 – 11 bars. Either nickel steel or coal-manganese steel is used in the cargo tanks. Semi-pressurised carriers with spherical tanks utilise the same steel quality as in cylinder tanks. The cylinder tanks are often a combination of twin tanks that are situated longitudinally of the ship, and a single situated abeam. The tanks are placed below deck, but some vessels also have cargo tanks on deck. This information is, at all times, specified in IMO Certificate of Fitness. In the IMO Certificate of Fitness, there is also a summary of cargo the vessel can carry.
The tanks are placed in "cradle-like" constructions and are welded to one of the cradles; the other cradle then functions as cargo tank support by expansion of the tank. The tanks are either strapped down with steel bands or the brackets are welded on to prevent the tanks from floating up. Between the cradle and the tank shell there is a layer of hard wood that acts as a fender to prevent damage to the cargo tank against the cradle, and acts as insulation against the steel in the cradle. On some vessels, the cargo tanks are attached to one of the cradles, and free in the other cradle for free expansion of the cargo tank. The spherical tanks are also installed in a "cradle-like" construction, and brackets (anti float) are welded on top of the cargo tank to prevent the cargo tanks from floating up. The support goes towards a bracket in the hull of the tanker, either up under deck or in the ship side.
Actual cargoes for Semi-pressurised gas carriers are LPG, LEG, Ammonia, Ethylene and some chemical gases.
Semi-pressurised gas carriers are the type of gas carriers that is most flexible for change of cargo and cargo handling.

Advantages:

- **Very flexible, can load and unload temperate cargo.**
- **Can heat the cargo while at sea and while discharging.**
- **Can transport fully cooled cargo, and thereby handle heavier cargo, lower temperature, and larger density. (Notice the safety valves set point).**
- **Easier tank construction than fully pressurised tankers.**
- **Can cool the cargo on route, no dependence at loading to remove excess pressure.**

Disadvantages:

- **Expensive to build, costly cargo handling equipment.**
- **Complicated to operate because of the cargo handling equipment.**
- **Uses more energy than fully pressurised tankers.**
- **Limited cargo amount (maximum approximate15000 m^3).**

Semi-pressurised tankers with deck cargo tank or some transverse cargo tanks can have stability problems in loading/discharging. This is specified in the operating manual and the stability book for the tanker, and the operators onboard must consider this.

3.7.2 Semi pressurised tankers (Combined gas/chemical)

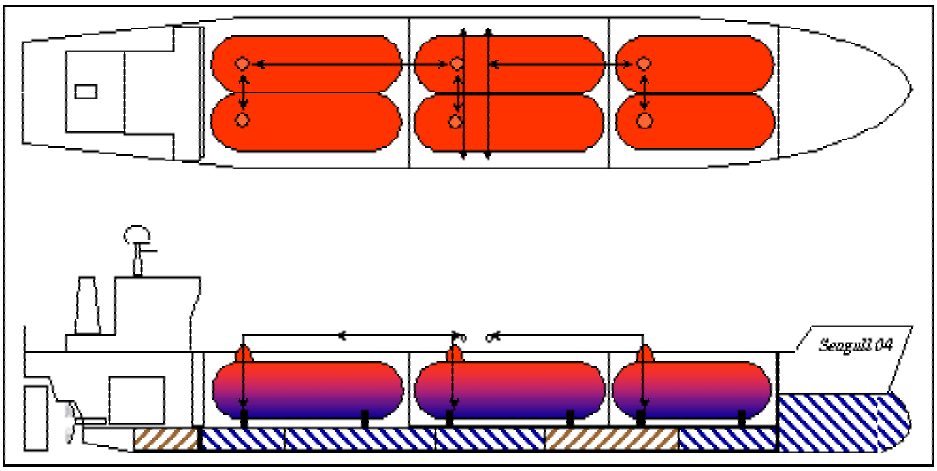
These gas carriers are constructed like other Semi pressurised tankers, but they are classified both according to IMO gas and chemical codes. This involves separate liquid and vapour lines from each tank to the manifold, in order to segregate all cargo tanks from each other. This means that this type of gas carriers can load equally as much different cargo as they have cargo tanks. The cargo tanks on this type of gas carrier are the independent type C cylinder, generally single transverse or small alongside twin tanks.
Cargo tanks, lines, and valves are constructed in stainless steel, and these gas carriers are equipped with indirect cargo cooling plant in addition to cascade cargo cooling plant. They are constructed to transport cargo from $-104^{o}C$ to $60^{o}C$. The indirect cargo cooling plant is often equipped with a coil welded outside the tank shell, where Ethanol is used either to cool or heat the tank steel. When cooling the tank steel, the Ethanol is cooled with the help of freon (R22) cooling plant. The Ethanol is also utilised to heat the tank steel; it is then heated with the tanker steam in a heat exchanger and pumped in and around the coils.
These gas carriers are normally designed for 3 - 4 bars excess pressure and are built in sizes from 4000 m^3 up to 15000 m^3.
Actual cargo LPG / NH_3 / LEG / chemical gases and chemicals.

Advantages:

- **The tankers are very flexible, can transport both chemicals and gas.**
- **Tanks and lines are stainless steel.**
- **Direct and indirect cooling/heating.**
- **Can load and discharge tempered cargo and fully cooled cargo down to -104°C.**
- **Access to many smaller ports/harbours because of relatively little draught.**

Disadvantages:

- **Expensive to build.**
- **Demanding to operate because of complicated cargo handling equipment.**
- **Limited cargo volume because of the tanker's size.**
- **The stability is a problem when loading/unloading when there are many transverse cargo tanks or deck cargo tanks. This is specified in the operational manual and the stability book.**



3.8 FULLY REFRIGERATED CARRIERS

Following semi-pressurised gas carriers, the first atmospheric pressure gas carrier was delivered at the end of the 1950s. These gas carriers are built in sizes from 15000 m^3 to 120000 m^3, and are designed for excess tank pressure less than 0,7 bars. These gas carriers are built either with independent tank type A or type B as prismatic or spherical tanks, or with membrane tanks. With prismatic or membrane tanks the volume of the hull is utilised, and tank construction is below deck. With spherical tanks, about half of the cargo tank is above deck because the vessel's hull is lower than what you find with prismatic or membrane tanks.

3.8.1 Fully refrigerated LPG carriers

The cargo tanks on f**ully refrigerated LPG carriers** are normally built of low temperature carbon-manganese steel. The cargo tanks are designed for LPG, Ammonia and some chemical gases with minimum temperature of –48°C. The cargo tanks are normally insulated either with Polyurethane or Polystyrene. Some of the older fully refrigerated gas carriers have Perlite as tank insulation.

Fully refrigerated gas carriers are normally equipped with independent type A or B prismatic cargo tank or membrane tanks. Fully refrigerated carriers with independent tank type A must have a full secondary barrier. This is achieved by using low temperature steel in the hull structure around the cargo tank.

If independent tank type B is utilised either prismatic or spherical tanks, only a partly secondary barrier is demanded. This is achieved by utilising low temperature steel in the hull under the cargo tank.

Independent prismatic cargo tanks are normally divided into two in longitudinal direction with a centre bulkhead that runs to the top of the tank dome. The centre

bulkhead is built to improve the stability on the carriers by reducing the effect of the free liquid surface when the tanks are loaded.
There are normally one or more valves in the centre bulkhead that is called intermediate valves. These intermediate valves are installed down in the pump sump for the liquid to flow from one side to the other. It is important that the intermediate valves are closed when there is no loading or discharging of cargo. Normally there are two pumps in each cargo tank.
With the intermediate valves open, one can discharge the entire cargo tank with one pump.

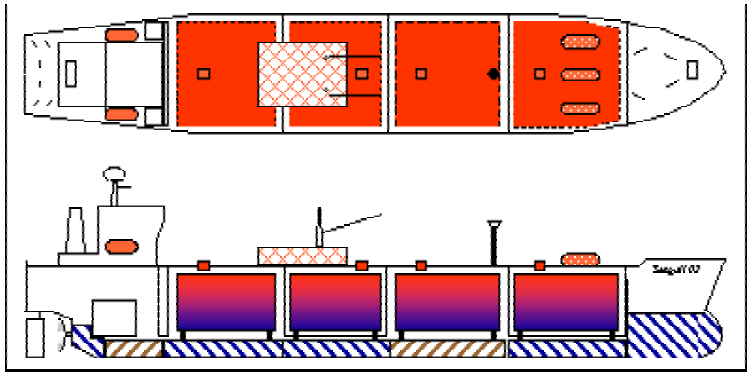
Fully refrigerated carriers with membrane tanks are without a centre bulkhead. Such gas carriers are built with a trunk on deck that the membrane tank is formed out of, and thereby reduces the effect of the free liquid surface.
Fully refrigerated carriers are generally equipped with the same cargo handling equipment as Semi-pressurised carriers. Some carriers also have coils in the pump sump that is used for liquid free the tank, hot gas is blown through the coils. Some carriers are also equipped with strip lines in the tank that either are connected to ejectors or transportable membrane pumps, this is utilised when loading naphtha etc. Some atmospheric pressure tankers do not have booster pumps or heat exchangers (cargo heaters).
Actual cargo for this type of gas carrier is LPG, Ammonia, Naphtha, and some chemical gases, such as, Propylene, Butadiene and VCM. Information of the type of cargo the tanker transports is located in IMO Certificate of Fitness.
When atmospheric pressure gas carrier are carrying flammable products, the hold space or the inter-barrier space must have a content of neutral atmosphere with either dry inert gas or dry nitrogen. When carrying non-flammable products, one utilises dry air or dry nitrogen on the hold space.
This gas carrier type carries a lot of LPG from the Persian Gulf to the Far East and USA. Ammonia is transported from The Black Sea to USA and the Far East.

Advantages:

- **Transports large weight in proportion to volume because the cargo is at all times loaded and transported at atmospheric pressure.**
- **Easier cargo tank construction than Semi pressurised tanker**
- **Tanks and lines are insulated.**
- **Have large cargo cooling plant.**
- **Large tankers are more efficient (cargo weight).**

Disadvantages:

- **Not so flexible for cargo change as Semi pressurised tankers.**
- **Pressure limitation, not possible to heat up cargo on route.**
- **Carrier without heat exchanger (cargo heater) can only unload at atmospheric pressure (fully cooled).**
- **Limited access on terminals and ports with limitations to draught.**



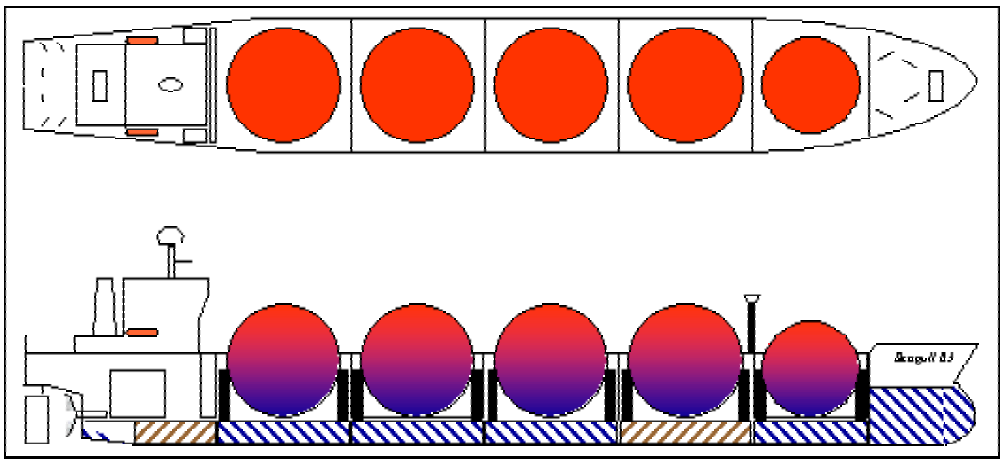
3.8.2 Fully refrigerated LNG carriers

These gas carriers are special as they are designed for loading gas at atmospheric pressure with a temperature down to –163°C. **Fully refrigerated LNG carriers** are either built with independent tanks type B Moss-Rosenberg patent with spherical tanks or French patents that utilises membrane tanks.

Spherical tanks of Moss Rosenberg patent are built in aluminium. French patents with membrane tanks are built either in stainless steel, 9% nickel steel or ferro nickel steel that have a 36% nickel content. Common for all these steel types is that they have a thermal expansion coefficient close to 0.These gas carriers are built from 20000 m^3 to 125000 m^3. The largest LNG carriers are, at all times, contracted on basis of long cargo contracts over about 25 years. This is because these tankers are very expensive to build, and are designed for LNG trade. The LNG tankers compete with gas transportation in pipelines on shore, and the sea transport amount to about 5% of the total LNG transport.

These tankers are special in that the vapour boil off from the cargo is utilised as fuel to the vessels propulsion. For the large LNG tanker, the vapour boil off is between 0,18% to 0,25% of the cargo capacity per 24 hours. It is possible to produce cargo-cooling plants for the large LNG tankers, but to cool 125000 m^3 LNG about 6000 kW/h is required. This indicates that this is too expensive, and it is more appropriate to utilise the vapour boil off for propulsion. The smaller LNG tankers on the other hand have a cargo cooling plant, and they transport some in LPG/LNG/LEG trade.

LNG carriers have a special procedure for cooling the cargo tanks before loading, which is specified in the tanker's operation manuals and certificates. The tankers are equipped with a spray plant where Methane is pumped into the tank's spray line (perforated lines), which is installed inside the cargo tank. Understandably, one must cool the cargo tanks a considerable amount of degrees to be ready to load. One must never begin to load a cargo tank before there is $-136^{o}C$ in the middle of the tank, or by the tank's equator.



04- FREIGHTING

FREIGHTING

The right to charter has an international colouring. This is naturally because the activity over the world's oceans is linking countries, nations and traditions closer together and creates a need of uniformity. That is why common regulations concerning transporting products is so important, but still there is a long way to go.
Ship trading is risky, and in extreme cases this fact was recognised in the days of sail-ships. In these days the owners of the ships had a limited responsibility due to miscalculations, and where held responsible the limitations to the area accounted for was the value of the ship and the freight.
The rules concerning the responsibility during transport gives the answer to how far, and to which extend, the owner is responsible to the economical loss the cargo owner suffers by loss or damage on goods or by delay during the voyage while it still was in the ship's owner custody.

4.1 HISTORY

In the last century the ship owners signed off any responsibility due to damages during the voyage. Clauses were made to liberate the owners from almost everything. American cargo owners had agreements in the American court of law saying that many of these clauses had no value, in other words: the clauses liberating the ship owners responsibility due to miscalculations and negligence was not valid.
The motion was against the hip owners both in USA and Europe. The ship owners themselves decided that something had to be done, and in 1924 as a result of several maritime court conferences, "Bill of Lading" convention was established, called The Haag-Regulations. The Haag regulations was ratified of most maritime trading nations, and this resulted in an almost united regulation of the most important conflicts concerning transporting of goods, as well as the understanding of what a bill of landing shall contain and the responsibility connected to the information about the product.
Norway acknowledged the Haag regulations in 1938. Still the need to improve existed and after the conference in Stockholm in 1963, another protocol was developed with some proposals to improvements due to the Haag regulations. The convention changed in constitution and now called the Haag-Visby regulations.
The Haag-Visby regulations represent no longer fully and updated international accepted regulations, for instance to general cargo transporting.
A new conference was held in Hamburg and the purpose is that the Hamburg rules shall take over for the Haag-Visby rules when they are ratified by a satisfactory number of marine trading nations.

4.1.1 The Conventions decisions

Usually the parts in negotiations can request their desires concerning transport of a product or an entire ship cargo, by the commitment in a freight contract. But the participants can not make the deal totally as they want. The regulations in the "Bill of

Lading" has to be followed, and the amount the ship owner have to be responsible to, must be, according to the responsibility rules and not a smaller amount.
On the other hand, the opportunity to commit the shipping company to be responsible to a higher amount is available. So, there is no way to avoid the regulations due to the bill of lading and the transport responsibility according to the conclusions in the international Haag-Visby regulations.
In addition to the decisions by the court of law about the partner's deal, the customary practice will play an important role when it comes to how a freight contract shall be understood.
When the partners implicated have come to an agreement, a contract is established and ready to sign. This deal is called A «charter party». Such a deal was in the past considered to be a quit simple document. This is not the case any more. A number of the larger charterer have today their own charter party formula. It exists a number of different charter party formulas due to load and trade. It is quit obvious that a charter party for a load of cattle will have to consist of a number of regulations totally different from a ship carrying a cargo of gas or a ship carrying crude oil.
In freighting, a number of expressions which is important to be fully aware the meaning of, is used, therefore look at the enclosure list with commonly used expressions in the end of this part of the compendium.
As mentioned before a «charter party» is a contract about a transport mission. When the product is taken on board a document shall be issued called a "Bill of Lading". A Bill of Lading is a document confirming the acceptance of the cargo (product) to carry from one determination place to the other.
In bill of lading the ship owner is described as the freighter of the cargo, and the one who go cargo needed to be transported is called the charter.

4.1.2 Freighting in General

We shall now go through a little extra about the different ways of freighting, but first let us briefly say a little of what normally happens before the negotiations start. Thereafter we will talk some about the partners involved, the mechanisms in the market, and the shipping language with the expression habits, the rate system, the freight market, and a little about technicalities during negotiations.
Two of the partners often mentioned in freighting are the charter one having the cargo and the freighter whom is the ship owner. In a simple way, for example an oil company has a cargo and wishes this cargo to be shipped from the Arabian Gulf to SE Asia. So the company then contacts their broker in London delivering a brief description of the cargo. For example, 4500 metric tons of propylene, which is to be loaded in Al Jubail in the time 17-20th of May.
The London broker will then send off a telex with this cargo information and send this telex to his broker associated in various countries, based on this brokers knowledge and considerations due to where hip owners with suitable tonnage is established around the world. These brokers have a wide information of ship types and companies and when the ships are available which is extremely useful and necessary.
When it concerns shipping the free marketing mechanism is ruling. Offer and demand control the whole scenario. When little activity in the market, it referred to

as quit and slow. When the market is active, it is referred to as a lively demand. The freighting level will rarely be constant. In a n active market with lively demand the freight rates increase. This due to the fact that both ship owner and the broker instantly read which way the demand is going. Therefore the freight rate gets higher, and because there is shortage of tonnage, the oil company has no other alternate than to pay.
Similarly a quit market will lead the oil companies to acknowledge that there is no competition in market, and that ships want contracts, and since several is competing, the oil company can press the market down and have a ship with the lowest freight rate signed up. How far down the rate is pressed is dependent of the conditions. A ship owner will probably not choose to lay up the ship until the freight market is so low that the transporting income does not cover the running costs. In a short period the owners may choose to sail with loss, reading the market and consider this as a temporary down period. It is really extremely expensive to lie up the ships and then break open again. Further on the low rate over a longer period will lead to less contracting. When the market is strong and active, will on the other hand the contracting increase. The same is to be said about buying and selling «second hand tonnage».
Later on we will, when viewing the different types of transport forms, discuss the different shipping expressions. The shipping language itself is English, but what make it difficult to understand is all the abbreviations and special expressions. Some of these special expressions will be found in the loading instructions, so we will try to get the most important ones with us. Since the wars ended oil tankers have developed different rating systems, and the one valid these days is called «World scale».
In world scale (World-wide Tanker Normal Freight Scale) is abbreviated to WS or W, and we find a number of basis rates for oil cargo voyages between typical disembarkation ports and receiving ports throughout the world.

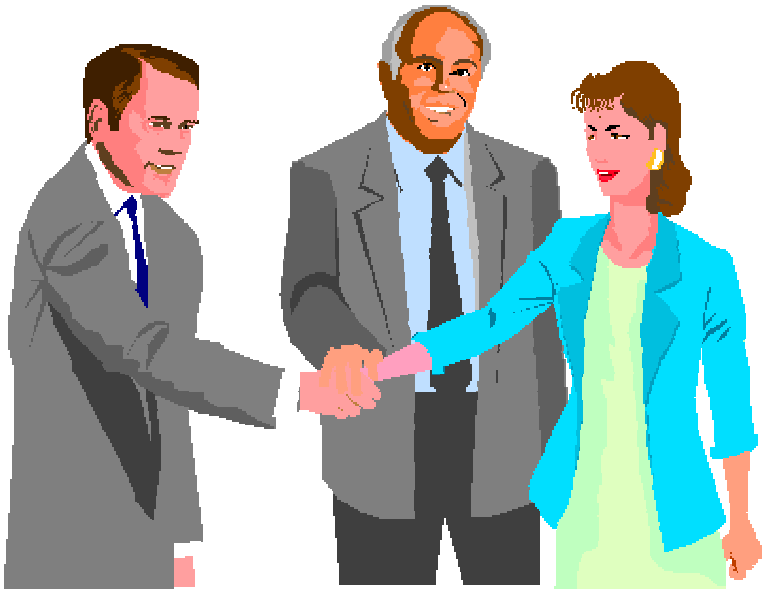
4.1.3 Basic Rate

The basic rate is calculated and intended a standard oil tanker with a loading capacity of 75000 metric ton, and an average speed of 14,5 knots, and a day and night consumption estimated to 55 metric tons HVF (heavy fuel) and 100 metric tons to other purposes, plus 5 metric tons in each port.
When the partners have agreed, the contract is written. The brokers then draw the contract, usually on a standard formula called a Charter Party. Usually the charterer's broker finishes the charter party and often signs the contract on behalf of the charterer.
The owner's broker usually signs the charter party according to received power of attorney after the owner have controlled a «working copy» of the charter party Common procedure is that the charter himself sign the document. Often the owner or his broker who is signing the charter party on the ship owners behalf.
The broker as a connecting link is extremely important and must be accurate and see that no mistakes are being made which can cause conflicts leading to claims for compensation. He will often as the negotiations is ending, send a rundown with all the conditions agreed to, so both parts can read through it and confirm the conditions agreed on.

4.2 THE NEGOTIATION

The parts in the negotiations

1. **The ship owner** is the one offering the ship services due to transport of cargo
2. **The charterer** is the part who has cargo to transport and need tonnage.
3. **The broker** is the part negotiating a final contract between owner and charterer.



The parts have start the negotiations, the picture above symbolise only the negotiation, not the negotiation form.
Now a few words about the negotiations itself. Naturally no deepen details is mentioned. Let us go back to the oil company which had a cargo of 4500 metric tons from Al Jubail going to SE Asia:
The procedure in the negotiations can vary, but in this case the English broker sent the order to several of his broker connections in countries which he meant had suitable tonnage in hand, among others several Norwegian brokers. These brokers passes on the request from the oil company to the different owner connections.(many owners have their own charterer sections). Only few minutes after the Oil Company informed the market about the cargo, the order came ticking into the owners office around the world.
The owner «Transporter Gas» has just the oil tanker available, LPG «Seagull» which can load about 4500 metric tons of propylene and is found in the right position to be ready for loading at the requested time. The owner is Norwegian and it is morning, and no especial time difference between London and Oslo, so the owner is ready to set up LPG «Seagull». The owner work out the conditions and makes an offer which the Oslo broker send via London to the oil company. This offer stand on hold for

about half an hour in our example, **«subject reply within 1230 hours»,** this is due to the fact that a new opportunity is likely to occur sudden in the market, and rapid replays is necessary.
Such a primer offer is usually very short , there is no negotiations yet, but it is a way to check the interest in the market for business, **«subj. Details and C/P conditions».**
Ref. your order Ras Tanura - Europe pleased to offer you: Subj. Replay here 1230 hrs. Oslo time.
LPG «Seagull». 8250 metric tonn dwt. on 8,2 mtrs. Summer draft. (followed by a short description of the ship).

Loa/beam:	**126,1m/17,8m.**
Blt:	**1982/class GL/flag Norwegian.**
Tank cap:	**8073 cbm. (98%).**
Last 3 cargoes:	**Propylene.**
Cargo:	**Min. 4500 metric ton up to full cargo.**
Segregation.	**Max. 2 grades within vessel's natural segr.**
Load:	**One safe berth Al Jubail.**
Disch.	**One safe port SE Asia.**
Laycan:	**May 17/20 1994.**
Rate:	**68 USD/mt.**
Demurrage:	**USD 14000 pdpr (per day pro rata)**
Haag-Visby:	**Haag-Visby rules.**
GA/ARB:	**(general average, arbitration) London, English law to apply.**
WSHT:	**(worldscale`s hours terms)-72hrs. Laytime.**
TTL(total)	**2,5% commission on FRT/DEM.**
CP form:	**ASBATANK (Tanker Voyage Charter Party)**

Sub further terms details.
The Owner (company) will now wait in excitement for replay, so that a **"counter"** is received, meaning a counteroffer. May be nothing happens. Other shipping companies may have reacted even faster with a replay, a ship with better equipment and position or a better previous cargo history, that means what cargo the ship has been carrying on previous voyages. It can also happen that another owner offers a lower freight rate. But any way, in our example, this ship is favourable to the charterer. Mostly of our offer is accepted and we receive the following telex:

Subj. Reply London 1245hrs.

Accept discharge range.

Rate: 62 USD/mt.

DEM: USD 9000 PDRP

Naturally, in the cards played one has to compromise, and after negotiating to and from one agrees that the owner and the charterer commits to a rate on 62 USD/mt and a DEM 9000.
When the negotiations are completed, the charterer send a **rundown**, where the total contract is confirmed. The charter party is written later. The parts involved have committed themselves on the basis of negotiations and the rundown which have been read and accepted, but there is always written a charter party , and this is functioning like a contract between the owner and charterer. Earlier this was a relatively simple document written in a few lines describing the ship, cargo, freight and the voyage. Today a charter party is a extensive document with standard clauses which are supplied with several additional clauses (riders) which are fastened to the charter party. These additional clauses is regulating the charterer special needs or other more practical conditions connected to the transport.
Further on it can be clauses concerning responsibilities damaging the cargo, shut downs, clauses of war, dividing expenses and other information about the ship, which will be of interest to the charterer.

4.3 BILL OF LADING

Choose to enlighten the document Bill Of Lading before going further into the other variants of charter parties.
A bill of lading is defined as a document consisting of:
A confirmation from the owner on the acceptance of specific goods, cargo to transport (carry).
A promise to transport the goods to a certain destination.
A promise to deliver goods at a determinate place in return of the document "Bill Of Lading".
After receiving the cargo, the ship captain or the vessel's agent issues a Bill of Lading. This will be handed over to the shipper so that the cargo can be delivered to the one holding the original Bill of Lading (the shipper or the buyer). This third party is the one who owns the cargo and is the receiver.
We have different types of Bill of Ladings, but the regulations are the same. When the cargo is transported by an oil tanker, the cargo owners, after checking when the ship is ready to embark, deliver the cargo to the tank company's "Warehouse". The tank company then issues a "booking note" referring to the company's Bill of Lading conditions and this ensures that the Bill of Lading is issued when the cargo has been loaded. From time to time, this "booking note" is skipped over. The cargo is then simply received with a confirmation of the Bill of Lading, which confirms that the cargo is received for transport. If the cargo is loaded on board a known and named ship, the Bill of Lading will be an "Onboard" Bill of Lading. A Bill of Lading can also state that the transportation may be executed with more than just the owner's ship. This Bill of Lading is called a "Through" Bill of Lading.
A document for the whole transport can be issued, when transport is executed by car, ship, or railroad. This is called Combined Transports and the document is called a "Combined Transport Document."
Along the Norwegian coastline no Bill of Lading is used, but a **Freight-bill** is issued instead. The strict rules for Bill of Lading responsibilities do not apply to the Freight-bill. In special areas, like the Northern Sea and in North Atlantic trade, a Bill of

Lading is not always used. However, a document referred to as **"Waybill"** is used and this document is not enforced as a Bill of Lading.

The Bill of Lading shall state the day and place where issued along with the shipper's name.
In addition, a recipient Bill of Lading will state the destination for cargo delivery.
An Onboard Bill of Lading will provide the ship's name, nationality and location where the cargo was loaded.

Further, if the shipper demands, the following will be noted:

The type of cargo and either the cargo weight measure or quantity of goods, based on the shipper's written task.
The shipper will deliver the necessary identification marks in writing, before the loading starts, provided that the marks are clearly indicated on the cargo.
The visible condition of the cargo.
On the receiver Bill of Lading, the day receiving the cargo. On the Onboard Bill of Lading, the day when the loading ended.
Where to and to whom the cargo will be delivered.
The size of the freight and the other terms related to the transportation and the cargo delivery.
The owner must be critical and should, of course, in no way avoid controlling the shipper's information, if there is any reason to suspect they are incorrect. If this is the case, he must control the information himself to ensure accuracy.
The shipper is accountable to the owner for the accuracy of the cargo information regarding his task or as requested in the Bill of Lading.
As receiver, the shipper can in the Bill of Lading suggest a special person, order or holder. The person standing as a receiver can give this right to another who can demand the cargo be delivered to him.
A Bill of Lading is issued in as many copies as the shipper demands, but the number should be referred to in text and the wording should be similar.

The regulations concerning the Bill of Lading responsibility are very strict. This is because a Bill of Lading is a negotiable document - a document which represents the cargo (the cargo's ID card) and which can be negotiable in form of buying and selling several times during the ships voyage. Therefore, the information in the Bill of Lading must be correct. The buyer of cargo, which is under transportation or scheduled for transport, has paid for the cargo and in return was granted the Bill of Lading. Upon arrival the buyer receives the cargo upon presenting the Bill of Lading. A Bill of Lading functions as a certificate that the cargo is as described in the document. Protests from the owner to the shipper cannot be set in force if the Bill of Lading has been acquired from a credulous third person.

When the person at the receiver location shows a Bill of Lading, he is regarded as the legitimate receiver of the cargo. It is enough that one Bill of Lading is presented where several are issued, if the others are delivered to their right owners. (This will be viewed on the next page, "Indemnity Clause"). If more receivers appear and can legitimate themselves by presenting examples of the Bill of Lading, the cargo will be held back until the correct receiver is found.

We already have mentioned that the Bill of Lading represents the cargo, and that this is valid as evidence -confirming- that the owner has accepted and loaded the cargo when no other information is available. Counter evidence cannot be produced if the Bill of Lading has been acquired in good faith from a third person.
If an owner knew, or ought to have known that information about the cargo was incorrect, there is no way to be free of responsibility. The Bill of Lading must in such a case show that this information proved otherwise.
The owner is also responsible to the third person if cargo damage or cargo lack has been kept hidden without being noted in the Bill of Lading, even when the owner should have discovered this information.
So, if the third party involved suffers loss when cashing in the Bill of Lading, trusting that the information stated is correct, the owner will be responsible. This is true when he has or should have realised that the information in this document was incorrect, and could have caused misunderstandings for a third party.
Law in its execution forces Haag-Visby regulations. There is no way to avoid any responsibility for the conditions.
The conditions in the Convention concerning responsibility for loss and damages is not an impediment for changes in the preserving of the cargo and the handling before loading and after discharging.
The owner, or someone he answers for, is responsible for losses regarding his obligation to keep the ship in seaworthy condition at the start of the voyage.
The Haag-Visby regulation's Bill of Lading paragraph does not apply to freight contracts. However, if a Bill of Lading is issued under a charter party, it must satisfy the conditions set in the Convention. The situation will then be to judge, based on the Haag-Visby regulations for all Bill of Lading issued for transport of a cargo, between two flag states when:
The Bill of Lading is issued in a country which has ratified the Convention, or:
The transport is from one port in a country using the Convention already, or:
The contract contains information which confirms that the country, according to its Convention rules or laws, have agreed to use the Convention in the transport situation.
When a ship is time chartered, the charterer will request that a Bill of Lading is issued. The same regulations concerning responsibility is valid as long as a document is issued. Also, the captain must make sure that no Bill of Lading is signed which could lead to claims of responsibility against the owner which was caused by incorrect description of the cargo. Here the same sort of difficulties as mentioned earlier can occur, therefore any remark concerning the cargo and its condition etc., must be noted in the document before signing it. A charterer will press a captain to issue a clean Bill of Lading regardless. Here the time charterer is important. A large reputable company can accept a "Back Letter" or "Letter of Indemnity" as satisfactory, but be careful and leave the decision to the owner. Be aware, that P/I companies do not cover the owner's loss if something goes wrong. The owner's would have to face claims of responsibility as a result of delivering cargo without having accepted the necessary Bill of Lading from the receiver, as required by law.
When delivering cargo, the captain must ensure and control that the cargo is exclusively delivered to the one presenting the original Bill of Lading. If another receiver than the one presenting in the Bill of Lading appears, it necessary to

examine if the person involved is right according to the transport declarations (notes added on the back side of the Bill of Lading, will confirm this).
Besides, the ship's captain must respond similarly due to the Bill of Lading, both when on time charter party or travel charter party and in the owners regular trading.

4.3.1 Indemnity Clause

This can cause some bother. If the original Bill of Lading cannot be produced, then the owner has a duty to deliver the cargo in exchange for a **"Letter of Indemnity"** (a written guaranty from the charterer). This is nothing like a bank guaranty, and cannot always be considered satisfactory security for the cargo delivery. Some oil companies use this, especially in short voyages. The owner's instruction must, in these cases, be followed by the captain in charge. The ship's captain has to show the utmost of caution when treating the loading contracts, especially the Bill of Lading. Any doubt whatsoever, remember to follow the owner's instructions, prospectively contact the owner's charterer office for further information.

4.4 FREIGHTING FORMS

A charter party is a document, which is a written confirmation between the owner and a charterer about a commissioned transport. Several standard charter party outlines exist concerning different types of freighting and their single type of cargo. Large charterer usually have their own formulas with specific conditions added. Be aware that the charter party outline also can be divided in sub groups, however this will not be viewed her. The central issue in any charter party is who the owner is and who is controlling the ship, the owner or the charterer and in some situations this can be hard to determine.

4.4.1 Voyage Charter Party

Voyage chartering is probably the most common type of freighting. A number of charter party formulas exist that are used. There will, in some cases, be clauses in the document, which almost completely favour of the charterer. Here the shipping company (owner) watches out for this and makes an effort to improve the terms. Whether this turns out to be a success is no guaranty, frequently there is a situation described as "take it or leave it". But in an active good market, with a shortage of ships available in the right location, then better conditions can possibly be negotiated with success. If the market activity is slow, the solution will be to accept the terms and be happy that the ship is in trading.
To get a more neutral charter party formula and better adjusted to the interests of both parties, two organisations have been especially working hard to accomplish standard charter party outlines. That is The Baltic and the International Maritime Conference (BIMCO) in Copenhagen and the English shipping organisation Chamber of Shipping of United Kingdom in London.
The best-known voyage charter party within the tank trade is "Tanker Voyage Charter Party". Most of the oil companies have their own charter party formulas which, broadly speaking, follow each other.
In this freighting form (voyage charter party), the owner is responsible for the operating expenses including bunker costs, as well as, the load/discharge port

expenses which are specified in the charter party, unless other terms are agreed to. Read the charter party.
In voyage freighting, the charterer makes an agreement on the freight before each single voyage. The ship is paid based upon the transported quantity. We will view the most important facts in the charter party negotiations.
We will look at a typical voyage charter party and go through the most important content. As you will notice, this is divided in two, **Part I and Part II.** The conclusions included in Part I have higher priority than the conditions in Part II. According to common interpretations practice, the written word is preferred over the printed, if these should come in conflict to each other. In the end of this chapter you will find a copy of a voyage charter party **"ASBATANKVOY"** which we use as the starting point here.
Preamble: Here is the information about the partners committed in this deal, as described in Part I and Part II, and which ship this concerns.

PART I
A: Description and position of vessel: The ship's loading capacity for the cargo to be transported (on oil tankers it is smart to note the pumping capacity). The loading capacity can be noted in i.e. m^3 or in metric tonnes. Here we should remember the expression: % MOLOO or % MOLCO. % MOLOO means "more or less in owner's option", in other words, the ship's captain can adjust the amount of cargo as specified by a % up or down. % MOLCO means "charter option". The position of the ship and when it can be ready in loading port.
B: Lay days/Cancelling (lay/can May 17-20 1994): Lay/can estimates the time frame (window) when the ship can arrive in loading port and be ready to load. If the ship appears ahead of time, it cannot demand to start loading before the lay days start, in this example 17th of May. If the ship arrives later than the cancelling date, in this example the 20th of May, the charterer may cancel the contract or re-negotiate.

C: Loading port(s) Range: It is important to agree on the load and discharge place, but this can be described in different ways:
A determined dock: for example berth 1, Mongstad.
A determined port: for example one safe port.
A determined area: for example one safe port, Europe.
An ordered port: for example Gibraltar for order.
Several ports: for example Rotterdam, Mongstad.
It is then the owner's duty to bring the ship to the determined port. In one part of the charter party, we have a so-called near clause which protects the owner from impediments which may arise after the charter party has been agreed to **"or so near there to as she may safely get and lie always afloat".**

D. Discharging port(s) range: The discharging ports can be agreed to as referred to in point "D".

E. Cargo description: It describes here how much and what kind of cargo the ship should load. MOLOO & MOLCO are possibly used. If several grades are to be loaded

the expression "Within vessel's natural segregation", abbreviated to (WVNS), can appear.

F. Freight rate: Here the freight rate is given in World Scale or prize pr unit either metric ton or cubic meter. World Scale is viewed earlier in this part of the compendium. The freight incomes in our example should be based on the agreement in the charter party, as follows: (185000 x 62 x 16,50): 100 **= US dollar 1,892,550.** For cargoes based on price pr. metric ton as in this example 65 USD/mt. We then multiply rate with estimate cargo as e.g. 4500 mt x 65 USD/mt = 292 500 USD.

G. Freight payable to: Noted here is the name and address of the receiver of the freight income. Paying currency is also noted.

H. Lay time: Normally agreed lay time in loading/discharging port is 72 hours (agreed in World Scale). This time is also dependent on the capacity of the discharging port, not only the ships. We will look closer at this when some of the parts in Part II of the charter party is viewed.

I. Demurrage: This is the compensation the owner can claim from the charterer if the charterer use a longer time for loading and discharging than estimated. Demurrage is agreed to when the charter party is negotiated and is likely to be set to a fixed cost per 24 hours. In our example we negotiated **a demurrage of US dollars 11500. - per 24 hours.**

We here show a demurrage calculation based on the information from a completed voyage charter party:

Total laytime according to CP	72	Timer
Agreed demurrage according CP	11 500	USD pdpr
Loading port		
Moored at loading port	17.05.94 06:00	
NOR delivered	17.05.94 06:00	
NOR accepted	17.05.94 06:00	
Commence loading	17.05.94 07:00	
Loading complete arm disconnected	18.05.94 22:00	
Total hours used on loading	39	Timer
Total hours NOR accepted to loading complete	40	Timer
Discharge port		
Arrival anchorage discharge port	06.06.94 03:30	

Moored discharge port	06.06.94 16:00	
NOR delivered	06.06.94 03:30	
NOR accepted	06.06.94 09:30	
Commence discharging	06.06.94 17:00	
Completed discharging arm disconnected	08.06.94 08:00	
Total hours used on discharging	39	Timer
Total hours NOR accepted to discharging comp.	46,5	Timer
Total hours on NOR in both ports	85,5	Timer
Total laytime according to CP	72	Timer
Demurrage base	13,5	Timer
Demurrage claim is then (11500 / 24 x 13,5)	6468,75	USD

Based on these facts, we now know what the charterer has to pay the owner if all delays are to be claimed on the terminals.

J. **Commission of:** Here it is written the percent owner has to pay e.g. 2,5%.

K. **The place of General average and arbitration:** Here it is stated if London or New York rules have to be used to settle claims.

L. **TOVALOP:** It is now cancelled

M. **Special provisions:** The amount of numbered additional clauses is given here.

Signatures: Here the owner and the charterer's broker sign the charter party.

This was Part I in the charter party. We will take a further look at the clauses in Part II of the charter party.

Before looking at Part II, let us be enlightened on the issue **"Subjects"!**. Often the charterer, before the affair is completed, takes into consideration certain circumstances, i.e. the cargo can be delivered to the loading place (subject stem), that the shipper accepts the ship, that the confirmation is approved be the company's management or that the cargo is being sold. Usually the agreement is a fact when the agreement is abandoned. Until this is a fact, the owner is bound. If the cargo is abandoned both parties are free.

PART II.
Now we will look at some of the clauses written in Part II of "ASBATANKVOY", you must read the charter party very closely, this is **IMPORTANT.**
Warranty – Voyage – Cargo: (Clause 1) The vessel must have all certificates valid that is required according to PART 1.
Dead freight: (clause 3) This clauses puts a claim on the charterer to come up with full cargo for the ship, but if he does not, the owner will suffer a freight loss. Full cargo is determined by what stands in the charter party Part I, A, iii. Therefore, if the charterer does not deliver full cargo the charterer must pay dead freight costs. Dead freight is the freight which compensates for the difference between the cargo the ship could have loaded if the charterer had supplied full cargo versus the real cargo the ship actually received. If the owner has had advantages like less load/discharge expenses and shorter time in loading and discharging, then this will be considered when calculating the dead freight. The owner should not be better off than he would have been with full load. If the charterer does not deliver cargo at all, the freight received is called fault freight.

For example, if our cargo is described at 4500 metric tonnes 5% MOLOO, the maximum cargo the captain can request (4500 : 100) x 105 = **4725 metric tonnes.**

The charterer will not give the vessel more cargo than 4725 mt even if the captain say he can take e.g. 4925 metric ton. When not receiving cargo the ship is booked for, the captain has to deliver a written protest in the load port, and make the shipper aware of the ship's capacity to load more, and at the same time calculate how much cargo is lacking.
In our example, we will find the dead freight claim based on the charter party.
Received cargo is **4650 metric tonnes.** The ship can load **4725 metric tonnes** based the charter party**.**

The dead freight base will be: (4725 - 4650) **= 75 metric tonnes**.

Naming loading and discharging port: (clause 4) Charterer have to name the load port 24 hours before the vessel readiness to sail from previous discharge port, bunkering port or when the charter party is signed.

Laydays: (clause 5) Commence of laytime does not start before the date and time stated in Part 1. If the vessel has not delivered NOR before 04:00 PM the cancelling date the charterer have option to cancel the chart.

Notice of readiness/Running time: (clause 6) This is the message, which is given when ready to load/discharge. NOR is not provided until the lay day (agreed to in Part I) starts.

NOR is given when the ship arrives and is shown the waiting place. The lay time starts to run 6 hours after NOR is sent. If the ship goes straight to port and starts loading/discharging, the lay time starts to run even before the end of the first mentioned 6 hours.

This will be specially noted in the charter party. It is important that all hours, concerning sending and receiving of NOR, is correct.
Running lay time is cancelled in the following situations:

- **From waiting place to load/discharge place.**
- **Ballast handling (when this prevents load/discharge).**
- **Time for stops which owner and ship causes.**

Time for tugboat, pilot, strike, etc.

Lay time: (clause 7). The determined number of hours for loading/discharging is written in this clause. Note specially here "and all other Charter's purpose whatsoever". The lay time only counts as long as the ship's loading/discharging capacity is fully used. If an impediment is caused due to the charterer's responsibilities, the time is counted.

Demurrage (clause 8): This is discussed on page 3 in this part.

Safe berthing/ Shifting: (clause 9) The charterer can rightfully shift the ship within the limit of load/discharging port. The freight does not cover this, but the lay time continues to run. The charterer must cover running expenses.

Pumping in and out: (clause 10). Cargo is loaded on the charterer account, when the cargo is received onboard it is on the owners account.

Ice: (clause 14). The ship should not trade in ice or be forced to follow an icebreaker. The important point here is that the ship's captain follow the nominated ports at all times. Read this text thoroughly.

Quarantine: (clause 17). Delay in time caused by quarantine is counted as lay time, if the quarantine was in force at the time the charterer nominated the port.

Agency: (clause 22). The company in the nominated load/discharging ports must use the charter agent. These agents should be considered to be the owner's agent and is paid by the owner.

Oil pollution prevention: (clause 26) The owner shall ensure that the ship captain is performing the following:

1. Everything based on MARPOL 73/78, particularly Regulation9/Chapter 2 of the International Convention for the Prevention of Pollution from ships 1973.

2. Oil and oily water should be collected in the ships slop tank while cleaning tanks, and after a maximum settling time the separated water is pumped over board as stipulated in MARPOL 73/78.

3. There after the charterer should be informed of the amount of oil and water which is left on board in addition to details concerning slop left over from

earlier voyages, called collected washings. The charterer has the right to decide whether this slop will be delivered ashore or be kept on board to eventually be loaded on top of this (LOT.)

Bills of Lading: This clause is extremely important and comprehensive and has to be studied carefully. See the section of Bill of Lading chapter 3 in part 4

This was some of the printed clauses in Charter party ASBATANKVOY. The type of charter party vary from company to company. In addition to the printed clauses we have option to write specified clauses.

Association of Ship Brokers & Agents (U.S.A.), Inc.

October 1977

CODE WORD FOR THIS CHARTER PARTY:

ASBATANKVOY

TANKER VOYAGE CHARTER PARTY

PREAMBLE

Place Date

IT IS THIS DAY AGREED between

chartered owner/owner (hereinafter called the "Owner") of the

SS/MS (hereinafter called the "Vessel")

and (hereinafter called the "Charterer")

that the transportation herein provided for will be performed subject to the terms and conditions of this Charter Party, which includes this Preamble and Part I and Part II. In the event of a conflict, the provisions of Part I will prevail over those contained in Part II.

PART I

A. Description and Position of Vessel:

Deadweight: tons (2240 lbs.) Classed:

Loaded draft of Vessel on assigned summer freeboard ft. in. in salt water.

Capacity for cargo: tons (of 2240 lbs. each) % more or less, Vessel's option.

Coated: [ ] Yes [ ] No

Coiled: [ ] Yes [ ] No Last two cargoes:

Now: Expected Ready:

B. Laydays:

Commencing: Cancelling:

C. Loading Port(s):

Charterer's Option

D. Discharging Port(s):

Charterer's Option

E. Cargo:

Charterer's Option

F. Freight Rate: per ton (of 2240 lbs. each).

G. Freight Payable to: at

H. Total Laytime in Running Hours:

I. Demurrage per day:

J. Commission of % is payable by Owner to

on the actual amount freight, when and as freight is paid.

K. The place of General Average and arbitration proceedings to be London/New York (strike out one).

L. Tovalop: Owner warrants Vessel to be a member of TOVALOP scheme and will be so maintained throughout duration of this charter

M. Special Provisions:

IN WITNESS WHEREOF, the parties have caused this Charter, consisting of a Preamble, Parts I and II, to be executed in duplicate as of the day and year first above written.

Witness the signature of:

By:

Witness the Signature of:

By:

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PART II

1. WARRANTY - VOYAGE - CARGO. The vessel, classed as specified in Part I hereof, and to be so maintained during the currency of this Charter, shall, with all convenient dispatch, proceed as ordered to Loading Port(s) named in accordance with Clause 4 hereof, or so near thereunto as she may safely get (always afloat), and being seaworthy, and having all pipes, pumps and heater coils in good working order, and being in every respect fitted for the voyage, so far as the foregoing conditions can be attained by the exercise of due diligence, perils of the sea and any other cause of whatsoever kind beyond the Owner's and/or Master's control excepted, shall load (always afloat), from the factors of the Charterer a full and complete cargo of petroleum and/or its products in bulk, not exceeding what she can reasonably stow and carry over and above her bunker fuel, consumable stores, boiler feed, culinary and drinking water, and complement and their effects (sufficient space to be left in the tanks to provide for the expansion of the cargo), and being so loaded shall forthwith proceed, as ordered on signing Bills of Lading, direct to the Discharging Port(s), or so near thereunto as she may safely get (always afloat), and deliver said cargo. If heating of the cargo is requested by the Charterer, the Owner shall exercise due diligence to maintain the temperatures requested.

2. FREIGHT. Freight shall be at the rate stipulated in Part I and shall be computed on intake quantity (except deadfreight as per Clause 3) as shown on the Inspector's Certificate of Inspection. Payment of freight shall be made by Charterer without discount upon delivery of cargo at destination, less any disbursements or advances made to the Master or Owner's agents at ports of loading and/or discharge and cost of insurance thereon. No deduction of freight shall be made for water and/or sediment contained in the cargo. The services of the Petroleum Inspector shall be arranged and paid for by the Charterer who shall furnish the Owner with a copy of the Inspector's Certificate.

3. DEADFREIGHT. Should the Charterer fail to supply a full cargo, the Vessel may, at the Master's option, and shall, upon request of the Charterer, proceed on her voyage, provided that the tanks in which cargo is loaded are sufficiently filled to put her in seaworthy condition. In that event, however, deadfreight shall be paid at the rate specified in Part I hereof on the difference between the intake quantity and the quantity the Vessel would have carried if loaded to her minimum permissible freeboard for the voyage.

4. NAMING LOADING AND DISCHARGE PORTS.

(a) The Charterer shall name the loading port or ports at least twenty-four (24) hours prior to the Vessel's readiness to sail from the last previous port of discharge, or from bunkering port for the voyage, or upon signing this Charter if the Vessel has already sailed. However, Charterer shall have the option of ordering the Vessel to the following destinations for wireless orders:

	On a voyage to a port or ports in:
ST.KITTS	Carribean or U.S. Gulf loading port(s)
PORT SAID	Eastern Mediterranean or Persian Gulf loading port(s) (from ports west of Port Said.)

(b) If lawful and consistent with Part I and with the Bills of Lading, the Charterer shall have the option of nominating a discharging port or ports by radio to the Master on or before the Vessel's arrival at or off the following places:

Place	On a voyage to a port or ports in:
LAND'S END	United Kingdom/Continent (Hordeaux/Hamburg range) or Scandinavia (including Denmark)
SUEZ	Mediterranean (from Persian Gulf)
GIBRALTAR	Mediterranean (from Western Hemisphere)

(c) Any extra expense incurred in connection with any change in loading or discharging ports (so named) shall be paid for by the Charterer and any time thereby lost to the Vessel shall count as used Laytime.

5. LAYDAYS. Laytime shall not commence before the date stipulated in Part I, except with the Charterer's sanction. Should the Vessel not be ready to load by 4:00 o'clock P.M. (local time) on the cancelling date stipulated in Part I, the Charterer shall have the option of cancelling this Charter by giving Owner notice of such cancellation within twenty-four (24) hours after such cancellation date; otherwise this Charter to remain in full force and effect.

6. NOTICE OF READINESS. Upon arrival at customary anchorage at each port of loading or discharge, the Master or his agent shall give the Charterer or his agent notice by letter, telegraph, wireless or telephone that the Vessel is ready to load or discharge cargo, berth or no berth, and laytime, as hereinafter provided, shall commence upon the expiration of six (6) hours after receipt of such notice, or upon the Vessel's arrival in berth (i.e., finished mooring when at a sealoading or discharging terminal and all fast when loading or discharging alongside a wharf), whichever first occurs. However, where delay is caused to Vessel getting into berth after giving notice or readiness for any reason over which Charterer has no control, such delay shall not count as used laytime.

7. HOURS FOR LOADING AND DISCHARGING. The number of running hours specified as laytime in Part I shall be permitted the Charterer as laytime for loading and discharging cargo; but any delay due to the Vessel's condition or breakdown or inability of the Vessel's facilities to load or discharge cargo within the time allowed shall not count as used laytime. If regulations of the Owner or port authorities prohibit loading or discharging of the cargo at night, time so lost shall not count as used laytime; if the Charterer, shipper or consignee prohibits loading or discharging at night, time so lost shall count as used laytime. Time consumed by the vessel in moving from loading or discharge port anchorage to her loading or discharge berth, discharging ballast water or slops, will not count as used laytime.

8. DEMURRAGE. Charterer shall pay demurrage per running hour and pro rata for a part thereof at the rate specified in Part I for all time that loading and discharging and used laytime as elsewhere herein provided exceeds the allowed laytime elsewhere herein specified. If, however, demurrage shall be incurred at ports of loading and/or discharge by reason of fire, explosion, storm or by a strike, lockout, stoppage or restraint of labor or by breakdown of machinery or equipment in or about the plant of the Charterer, supplier, shipper or consignee of the cargo, the rate of demurrage shall be reduced one-half of the amount stated in Part I per running hour or pro rata for part of an hour for demurrage so incurred. The Charterer shall not be liable for any demurrage for delay caused by strike, lockout, stoppage or restraint of labor for Master, officers and crew of the Vessel or tughout or pilots.

9. SAFE BERTHING - SHIFTING. The vessel shall load and discharge at any safe place or wharf, or alongside vessels or lighters reachable on her arrival, which shall be designated and procured by the Charterer, provided the Vessel can proceed thereto, lie at, and depart therefrom always safely afloat, any lighterage being at the expense, risk and peril of the Charterer. The Charterer shall have the right of shifting the Vessel at ports of loading and/or discharge from one safe berth to another on payment of all towage and pilotage shifting to next berth, charges for running lines on arrival at and leaving that berth, additional agency charges and expense, customs overtime and fees, and any other extra port charges or port expenses incurred by reason of using more than one berth. Time consumed on account of shifting shall count as used laytime except as otherwise provided in Clause 15.

10. PUMPING IN AND OUT. The cargo shall be pumped into the Vessel at the expense, risk and peril of the Charterer, and shall be pumped out of the Vessel at the expense of the Vessel, but at the risk and peril of the Vessel only so far as the Vessel's permanent hose connections, where delivery of the cargo shall be taken by the Charterer or its consignee. If required by Charterer, Vessel after discharging is to clear shore pipe lines of cargo by pumping water through them and time consumed for this purpose shall apply against allowed laytime. The Vessel shall supply her pumps and the necessary power for discharging in all ports, as well as necessary hands. However, should the Vessel be prevented from supplying such power by reason of regulations prohibiting fires on board, the Charterer or consignee shall supply, at its expense, all power necessary for discharging as well as loading, but the Owner shall pay for power supplied to the Vessel for other purposes. If cargo is loaded from lighters, the Vessel shall furnish steam at Charterer's expense for pumping cargo into its Vessel, if requested by the Charterer, providing the Vessel has facilities for generating steam and is permitted to have fires on board. All overtime of officers and crew incurred in loading and/or discharging shall be for account of the Vessel.

11. HOSES: MOORING AT SEA TERMINALS. Hoses for loading and discharging shall be furnished by the Charterer and shall be connected and disconnected by the Charterer, or, at the option of the Owner, by the Owner at the Charterer's risk and expense. Laytime shall continue until the hoses have been disconnected. When Vessel loads or discharges at a sea terminal, the Vessel shall be properly equipped at Owner's expense for loading or discharging at such place, including suitable ground tackle, mooring lines and equipment for handling submarine hoses.

12. DUES - TAXES - WHARFAGE. The Charterer shall pay all taxes, dues and other charges on the cargo, including but not limited to Customs overtime on the cargo, Venezuelan Habilitation Tax, C.I.M. Taxes at Le Havre and Portuguese Imposto de Comercio Maritime. The Charterer shall also pay all taxes on freight at loading or discharging ports and any unusual taxes, assessments and governmental charges which are not presently in effect but which may be imposed in the future on the Vessel or freight. The Owner shall pay all dues and other charges on the Vessel (whether or not such dues or charges are assessed on the basis of quantity of cargo), including but not limited to French droits de quai and Spanish derramas taxes. The Vessel shall be free of charges for the use of any wharf, dock, place or mooring facility arranged by the Charterer for the purpose of loading or discharging cargo; however, the Owner shall be responsible for charges for such berth when used solely for Vessel's purposes, such as awaiting Owner's orders, tank cleaning, repairs, etc. before, during or after loading or discharging.

13. (a). CARGOES EXCLUDED VAPOR PRESSURE. Cargo shall not be shipped which has a vapor pressure at one hundred degrees Fahrenheit (100 deg F.) in excess of thirteen and one-half pounds (13.5 lbs.) as determined by the current A.S.T.M. Method (Reid) D-323.

(b) FLASH POINT. Cargo having a flash point under one hundred and fifteen degrees Fahrenheit (115 deg F.) (closed cup) A.S.T.M. Method D-56 shall not be loaded from lighters but this clause shall not restrict the Charterer from loading or topping off Crude Oil from vessels or barges inside or outside the bar at any port or place where bar conditions exist.

14. (a). ICE. In case port of loading or discharge should be inaccessible owing to ice, the Vessel shall direct her course according to Master's judgment, notifying by telegraph or radio, if available, the Charterers, shipper or consignee, who is bound to telegraph or radio orders for another port, which is free from ice and where there are facilities for the loading or reception of the cargo in bulk. The whole of the time occupied from the time the Vessel is diverted by reason of the ice until her arrival at an ice-free port of loading or discharge, as the case may be, shall be paid for by the Charterer at the demurrage rate stipulated in Part I.

(b) If on account of ice the Master considers it dangerous to enter or remain at any loading or discharging place for fear of the Vessel being frozen in or damaged, the Master shall communicate by telegraph or radio, if available, with the Charterer, shipper or consignee of the cargo, who shall telegraph or radio him in reply, giving orders to proceed to another port as per Clause 14 (a) where there is no danger of ice and where there are the necessary facilities for the loading or reception of the cargo in bulk, or to remain at the original port at their risk, and in either case Charterer to pay for the time that the Vessel may be delayed, at the demurrage rate stipulated in Part I.

15. TWO OR MORE PORTS COUNTING AS ONE. To the extent that the freight rate standard of reference specified in Part I F hereof provides for special groupings or combinations of ports or terminals, any two or more ports or terminals within each such grouping or combination shall count as one port for purposes of calculating freight and demurrage only, subject to the following conditions:

(a) Charterer shall pay freight at the highest rate payable under Part I F hereof for a voyage between the loading and discharge ports used by Charterer.

(b) All charges normally incurred by reason of using more than one berth shall be for Charterer's account as provided in Clause 9 hereof.

(c) Time consumed shifting between the ports or terminals within the particular grouping or combination shall not count as used laytime.

(d) Time consumed shifting between berths within one of the ports or terminals of the particular grouping or combination shall count as used laytime.

16. GENERAL CARGO. The Charterer shall not be permitted to ship any packaged goods or non-liquid bulk cargo of any description, the cargo the Vessel is to load under this Charter is to consist only of liquid bulk cargo as specified in Clause I.

17. (a). QUARANTINE. Should the Charterer send the Vessel to any port or place where a quarantine exists, any delay thereby caused to the Vessel shall count as used laytime, but should the quarantine not be declared until the Vessel is on passage to such port, the Charterer shall not be liable for any resulting delay.

(b) FUMIGATION. If the Vessel, prior to or after entering upon this Charter, has docked or docks at any wharf which is not rat-free or stegomyia-free, she shall, before proceeding to a rat-free or stegomyia-free wharf, be fumigated by the Owner at his expense, except that if the Charterer ordered the Vessel to an infected wharf the Charterer shall bear the expense of fumigation.

18. CLEANING. The Owner shall clean the tanks, pipes and pumps of the Vessel to the satisfaction of the Charterer's Inspector. The Vessel shall not be responsible for any admixture if more than one quality of oil is shipped, nor for leakage, contamination or deterioration in quality of the cargo unless the admixture, leakage, contamination or deterioration results from (a) unseaworthiness existing at the time of loading or at the inception of the voyage which was discoverable by the exercise of due diligence, or (b) error or fault of the servants of the Owner in the loading, care or discharge of the cargo.

19. GENERAL EXCEPTIONS CLAUSE. The Vessel, her Master and Owner shall not, unless otherwise in this Charter expressly provided, be responsible for any loss or damage, or delay or failure in performing hereunder, arising or resulting from:- any act, neglect, default or barratry of the Master, pilots, mariners or other servants of the Owner in the navigation or management of the Vessel; fire, unless caused by the personal design or neglect of the Owner; collision, stranding or peril, danger or accident of the sea or other navigable waters; saving or attempting to save life or property; wastage in weight or bulk, or any other loss or damage arising from inherent defect, quality or vice of the cargo; any act or omission of the Charterer or Owner, shipper or consignee of the cargo, their agents or representatives; insufficiency of packing; insufficiency or inadequacy or marks; explosion, bursting of boilers, breakage of shafts, or any latent defect in hull, equipment or machinery; unseaworthiness of the Vessel unless caused by want of due diligence on the part of the Owner to make the Vessel seaworthy or to have her properly manned, equipped and supplied; or from any other cause of whatsoever kind arising without the actual fault of privity of the Owner. And neither the Vessel nor Master or owner, nor the Charterer, shall, unless otherwise in this Charter expressly provided, be responsible for any loss of damage or delay or failure in performing hereunder, arising or resulting from:- Act of God; act of war; perils of the seas; act of public enemies, pirates or assailing thieves; arrest or restraint of princes, rulers or people; or seizure under legal process provided bond is promptly furnished to release the Vessel or cargo; strike or lockout or stoppage or restraint of labor from whatever cause, either partial or general; or riot or civil commotion.

20. ISSUANCE AND TERMS OF BILLS OF LADING.

(a) The Master shall, upon request, sign Bills of Lading in the form appearing below for all cargo shipped but without prejudice to the rights of the Owner and Charterer under the terms of this Charter. The Master shall not be required to sign Bills of Lading for any port which, the Vessel cannot enter, remain at and leave in safety and always afloat nor for any blockaded port.

(b) The carriage of cargo under this Charter Party and under all Bills of Lading issued for the cargo shall be subject to the statutory provisions and other terms set forth or specified in sub-paragraphs (i) through (vii) of this clause and such terms shall be incorporated verbatim or be deemed incorporated by the reference in any such Bill of Lading. In such sub-paragraphs and in any Act referred to therein, the word "carrier" shall include the Owner and the Chartered Owner of the Vessel.

(i) CLAUSE PARAMOUNT. This Bill of Lading shall have effect subject to the provisions of the Carriage of Goods by Sea Acts of the United States, approved April 16, 1936, except that if this Bill of Lading is issued at a place where any other Act, ordinance or legislation gives statutory effect to the International Convention for the Unification of Certain Rules relating to Bills of Lading at Brussels, August 1924, then this Bill of Lading shall have effect, subject to the provisions of such Act, ordinance or legislation. The applicable Act, ordinance or legislation (hereinafter called the "Act") shall be deemed to be incorporated herein and nothing herein contained shall be deemed a surrender by the Owner of any of its rights or immunities or an increase of any of its responsibilities or liabilities under the Act. If any term of this Bill of Lading be repugnant to the Act to any extent, such term shall be void to the extent but no further.

(ii) JASON CLAUSE. In the event of accident, danger, damage or disaster before or after the commencement of the voyage, resulting from any cause whatsoever, whether due to negligence or not, for which, or for the consequence of which, the Owner is not responsible, by statute, contract or otherwise, the cargo shippers, consignees or owners of the cargo shall contribute with the Owner in General Average to the payment of any sacrifices, losses or expenses of a General Average nature that may be made or incurred and shall pay salvage and special charges incurred in respect of the cargo. If a salving ship is owned or operated by the Owner, salvage shall be paid for as fully as if the said salving ship or ships belonged to strangers. Such deposit as the Owner or his agents may deem sufficient to cover the estimated contribution of the cargo and any salvage and special charges thereon shall, if required, be made by the cargo, shippers, consignees or owners of the cargo to the carrier before delivery.

(iii) GENERAL AVERAGE. General Average shall be adjusted, stated and settled according to York/Antwerp Rules 1950 and, as to matters not provided for by those rules, according to the laws and usages at the port of New York or at the port of London, whichever place is specified in Part I of this Charter. If a General Average statement is required, it shall be prepared at such port or place in the United States or United Kingdom, whichever country is specified in Part I of this Charter, as may be selected by the Owner, unless otherwise mutually agreed, by an Adjuster appointed by the Owner and approved by the Charterer. Such Adjuster shall attend to the settlement and the collection of the General Average, subject to customary charges. General Average Agreements and/or security shall be furnished by Owner and/or Charterer, and/or Owner and/or Consignee of cargo, if requested. Any cash deposit being made as security to pay General Average and/or salvage shall be remitted to the Average Adjuster and shall be held by him at his risk in a special account in a duly authorized and licensed bank at the place where the General Average statement is prepared.

(iv) BOTH TO BLAME. If the Vessel comes into collision with another ship as a result of the negligence of the other ship and any act, neglect or default of the Master, mariner, pilot or the servants of the Owner in the navigation or in the management of the Vessel, the owners of the cargo carried hereunder shall indemnify the Owner against all loss or liability to the other or non-carrying ship or her owners in so far as such loss or liability represents loss of, or damage to, or any claim whatsoever of the owners of said cargo, paid or payable by the other or recovered by the other or non-carrying ship or her owners as part of their claim against the carrying ship or Owner. The foregoing provisions shall also apply where the owners, operators or those in charge of any ships or objects other than, or in addition to, the colliding ships or object are at fault in respect of a collision or contact.

(v) LIMITATION OF LIABILITY. Any provision of this Charter to the contrary notwithstanding, the Owner shall have the benefit of all limitations of, and exemptions from, liability accorded to the owner or chartered owner of vessels by any statute or rule of law for the time being in force.

(vi) WAR RISKS. (a) If any port of loading or of discharge named in this Charter Party or to which the Vessel may properly be ordered pursuant to the terms of the Bills of Lading be blockaded, or

(b) If owing to any war, hostilities, warlike operations, civil war, civil commotions, revolutions or the operation of international law (a) entry to any such port of loading or of discharge or the loading or discharge of cargo at any such port be considered by the Master or Owners in his or their discretion dangerous or prohibited or (b) it be considered by the Master or Owners in his or their discretion dangerous or impossible for the Vessel to reach any such port of loading or discharge - the Charterers shall have the right to order the cargo or such part of it as may be affected to be loaded or discharged at any other safe port of loading or of discharge within the range of loading or discharging ports respectively established under the provisions of the Charter Party (provided such other port is not blockaded or that entry thereto or loading or discharge of cargo thereat is not in the Master's or Owner's discretion dangerous or prohibited). If in respect of a port of discharge no orders be received from the Charterers within 48 hours after they or their agents have received from the Owners a request for the nomination of a substitute port, the Owners shall then be at liberty to discharge the cargo at any safe port which they or the Master may in their or his discretion decide on (whether within the range of discharging ports established under the provisions of the Charter Party or not) and such discharge shall be deemed to be due fulfillment of the contract or contracts of affreightment so far as cargo so discharged is concerned. In the event of the cargo being loaded or discharged at any such other port within the respective range of loading or discharging ports established under the provisions of the Charter Party, the Charter Party shall be read in respect of freight and all other conditions whatsoever as if the voyage performed were that originally designated. In the event, however, that the Vessel discharges the cargo at a port outside the range of discharging ports established under the provisions of the Charter Party, freight shall be paid as for the voyage originally designated and all extra expenses involved in reaching the actual port of discharge and or discharging the cargo thereat shall be paid by the Charterers or Cargo Owners. In the latter event the Owners shall have a lien on the cargo for all such extra expenses.

(c) The Vessel shall have liberty to comply with any directions or recommendations as to departure, arrival, routes, ports of call, stoppages, destinations, zones, waters, delivery or in any otherwise whatsoever given by the government of the nations under whose flag the Vessel sails or any other government or local authority including any de facto government or local authority or by any person or body acting or purporting to act as or with the authority of any such government or authority or by any committee or person having under the terms of the war risks insurance on the vessel the right to give any such directions or recommendations. If by reason of or in compliance with any such directions or recommendations, anything is done or is not done such shall not be deemed a deviation.

If by reason of or in compliance with any such direction or recommendation the Vessel does not proceed to the port or ports of discharge originally designated or to which she may have been ordered pursuant to the terms of the Bills of Lading, the Vessel may proceed to any safe port of discharge which the Master or Owners in his or their discretion may decide on and there discharge the cargo. Such discharge shall be deemed to be due fulfillment of the contract or contracts of affreightment and the Owners shall be entitled to freight as if discharge has been effected at the port or ports originally designated or to which the vessel may have been ordered pursuant to the terms of the Bills of Lading. All extra expenses involved in reaching and discharging the cargo at any such other port of discharge shall be paid by the Charterers and/or Cargo Owners and the Owners shall have a lien on the cargo for freight and all such expenses.

(vii) DEVIATION CLAUSE. The Vessel shall have liberty to call at any ports in any order, to sail with or without pilots, to tow or to be towed, to go to the assistance of vessels in distress, to deviate for the purpose of saving life or property or of landing any ill or injured person on board, and to call for fuel at any port or ports in or out of the regular course of the voyage. Any salvage shall be for the sole benefit of the Owner.

21. LIEN. The Owner shall have an absolute lien on the cargo for all freight, deadfreight, demurrage and costs, including attorney fees, of recovering the same, which lien shall continue after delivery of the cargo into the possession of the Charterer, or of the holders of any Bills of Lading covering the same or of any storageman.

22. AGENTS. The Owner shall appoint Vessel's agents at all ports.

23. BREACH. Damages for breach of this Charter shall include all provable damages, and all costs of suit and attorney fees incurred in any action hereunder.

24. ARBITRATION. Any and all differences and disputes of whatsoever nature arising out of this Charter shall be put to arbitration in the City of New York or in the City of London whichever place is specified in Part I of this charter pursuant to the laws relating to arbitration there in force, before a board of three persons, consisting of one arbitrator to be appointed by the Owner, one by the Charterer, and one by the two so chosen. The decision of any two of the three on any point or points shall be final. Either party hereto may call for such arbitration by service upon any officer of the other, wherever he may be found, of a written notice specifying the name and address of the arbitrator chosen by the first moving party and a brief description of the disputes or differences which such party desires to put to arbitration. If the other party shall not, by notice served upon an officer of the first moving party within twenty days of the service of such first notice, appoint its arbitrator to arbitrate the dispute or differences specified, then the first moving party shall have the right without further notice to appoint a second arbitrator, who shall be a disinterested person with

precisely the same force and effect as if said second arbitrator has been appointed by the other party. In the event that the two arbitrators fail to appoint a third arbitrator within twenty days of the appointment of the second arbitrator, either arbitrator may apply to a Judge of any court of maritime jurisdiction in the city abovementioned for the appointment of a third arbitrator, and the appointment of such arbitrator by such Judge on such application shall have precisely the same force and effect as if such arbitrator had been appointed by the two arbitrators. Until such time as the arbitrators finally close the hearings either party shall have the right by written notice served on the arbitrators and on an officer of the other party to specify further disputes or differences under this Charter for hearing and determination. Awards made in pursuance to this clause may include costs, including a reasonable allowance for attorney's fees, and judgement may be entered upon any award made hereunder in any Court having jurisdiction in the premises.

25. SUBLET. Charterer shall have the right to sublet the Vessel. However, Charterer shall always remain responsible for the fulfillment of this Charter in all its terms and conditions.

26. OIL POLLUTION CLAUSE. Owner agrees to participate in Charterer's program covering oil pollution avoidance. Such program prohibits discharge overboard of all oily water, oily ballast or oil in any form of a persistent nature, except under extreme circumstances whereby the safety of the vessel, cargo or life at sea would be imperiled.

Upon notice being given to the Owner that Oil Pollution Avoidance controls are required, the Owner will instruct the Master to retain on board the vessel all oily residues from consolidated tank washings, dirty ballast, etc., in one compartment, after separation of all possible water has taken place. All water separated to be discharged overboard.

If the Charterer requires that demulsifiers shall be used for the separation of oil/water, such demulsifiers shall be obtained by the Owner and paid for by Charterer.

The oil residues will be pumped ashore at the loading or discharging terminal, either as segregated oil, dirty ballast or co-mingled with cargo as it is possible for Charterers to arrange. If it is necessary to retain the residue on board co-mingled with or segregated from the cargo to be loaded, Charterers shall pay for any deadfreight so incurred.

The Charterer agrees to pay freight as per the terms of the Charter Party on any consolidated tank washings, dirty ballast, etc., retained on board under Charterer's instructions during the loaded portion of the voyage up to a maximum of 1% of the total deadweight of the vessel that could be legally carried for such voyage. Any extra expenses incurred by the vessel at loading or discharging port in pumping ashore oil residues shall be for Charterer's account, and extra time, if any, consumed for this operation shall count as used laytime.

BILL OF LADING

Shipped in apparent good order and condition by

on board the Steamship/Motorship

whereof is Master, at the port of

to be delivered at the port of

or so near thereto as the Vessel can safely get, always afloat, unto

or order on payment of freight at the rate of

This shipment is carried under and pursuant to the terms of the contract/charter dated New York/London

between and , as Charterer, and all the terms whatsoever of the said contract/charter except the rate and payment of freight specified therein apply to and govern the rights of the parties concerned in this shipment.

In witness whereof the Master has signed Bills of Lading of this tenor and date, one of which being accomplished, the others will be void.

Dated at this day of

Master

This Charter Party is a computer generated copy of the ASBATANKVOY form, printed under licence from the Association of Ship Brokers & Agents (U.S.A), Inc., using software which is the copyright of Strategic Software Limited.

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4.5 TIME CHARTER PARTY

Besides voyage freighting, the time charter party is the most important form of chartering. Here the charterer hires a ship for a certain period of time, for example 1month, 6months, 2years or 15years. The time period can vary, but the principle will remain the same. In the chartered period, the time charterer can freely dispose the ship for his purposes within the frames which the charter party contract is drawn. He supplies cargo, instructs the ship, pays the variable expenses such as bunkers, canal- and harbour costs in load/discharging port. The owner is paid for the time the charterer uses the ship, either at a certain freight rate per tonnes dead weight per month, or as regular rate per 24 hours if it is a short termed time charter, or as a rolled-out sum per month or per fortnight. One can say that time charter is not quite as exciting as voyage chartering. If the ship is at sea, running satisfactory, the owner will have secure income, but the opportunity to make large profits if the activity in the market suddenly explodes, is shut off.

In association with an expensive new building, an owner is often interested in getting a long-term charter party for the ship. That will ease the business financing and offer security, especially in the first years of a ships active time. In long-term charter parties it is common practice to have a clause protecting the owner completely or partly of rising running costs (Escalation Clause).

There are several reasons for using the time charter. The regular shipment of large quantities of goods, for a special oil company, can be one reason. Others can be covered by using own tonnage, some will possibly be covered by time chartering available ships and the marginal need will be covered by voyage freight.

An owner may also have faith in a rise in freight rates and charter a ship for i.e. 6 months. When it is a success you earn money, when you fail you lose money because you do not get covered for the time freight or the variable expenses. Time chartering is a way to take advantage of the market, if the freight income is higher than the time charter rent you are paying.

Just as in the voyage charter party, the time charter party has many different formulas. During a time charter party, it is important that the description of the ship is accurate. The characteristics of the ship are of particular value for the time charterer, and the time charter (freight) he will pay.

If it is discovered that the owner has given incorrect information concerning the ship, or the ship does not fulfil the description, the charterer can demand a reduction or compensation for the damage he proves to suffer. In situations where the error is essential, the charterer can cancel the contract and demand compensation. With a time charter, a discussion most likely to appear, concerns the ships ability to load, load/discharge equipment, speed and the consumption of bunkers. A charterer will usually watch closely and make sure the ship redeems the claims in the charter party. Usually the time charter will be determined due to the dead weight of the ship indicated by the summer marking, and especially when it comes to talking about heavy cargo like oil.

The time charterer pays freight for the time disposal of the ship. So the ships speed and consumption is of great importance. The time charterer operates the ship and pays the bunkers expenses.

Over the years, the discussion has been endless concerning speed and consumption. This is likely to continue as long as time charters are involved. The owner is seeking

the business and has, therefore, described the ship as positively as possible, but since the charterer is paying he will watch the consumption from month to month.

A time-chartered ship is rented fully crewed and equipped, and the time charterer shall operate the ship. The captain's position on board can also appear difficult in this connection. The owner employs him for the responsibility of the ship handling, navigation and security. He also will take orders from the charterer concerning loading, discharging and sailing. The charterer will of course be interested in a quick load, quick sailing, and quick discharging. This can be a heavy load and interfere both with the safety and the conditions of the ship which may not always be in the interest of the owner. It is of extreme importance that the ships captain is not influenced by the charterer on behalf of the owner, but still within reasonable limits try to maintain a healthy relationship with the charterer. This relationship is very important.

In voyage freighting the owner pays all expenses connected to the voyage. In a time charter it is different, and therefore it is important to know whether the expense is put on the charterer or the owner's bill.
The owner company is obligated to have crew and a seaworthy ship at the charterer's disposal.

The owner will be responsible for the following expenses:

- Salary and other crew expenses
- Food
- Ships insurance
- Deck-and machine accessories
- Lubricating oil
- Repair expenses/dock setting
- Classification expenses
- Interests, part payments and administration

The following expenses will be paid by the charterer:

- Bunkers
- Port expenses
- Load/discharge expenses
- Pilot and canal expenses

The ship is delivered when the owner can present the ship to the charterer, in a port or out at sea at a determined position and on a determined date. The time charter is payable from the moment the ship is delivered. If the delivery is executed in a port the owner will, if nothing else is agreed to, pay the incoming expenses while the charterer is paying the outgoing expenses. If the ship arrives at delivery port in ballast, the usual procedure is to charge the charterer all the arrival expenses from the time the ship embarked the pilot on board, if nothing else is agreed to. Upon delivery time, it is important to check that all bunkers are surveyed on board. This is

the owner's property and must be paid for by the charterer. Usually both parties sign a delivery certificate.

4.5.1 Delivery Certificate

During the charter party's valid time period, the charterer may use the ship as he wishes and may plan voyages wherever he wants. This can be done within the limits set by the charter party. The charter can be limited by geographical limitations, ice conditions and wars, which affects the use of the ship. A ship can be used for world-wide trade, but with the enclosure "within institute warranties limits" (I.W.L.). When ordering a ship to areas where additional insurance are to be paid, the owner should preserve these expenses to be charged by the charterer.

The time charter has a set duration and is then returned to the owner. Some difficulties can arise, because it is hard to schedule a ship to be delivered on date, so a little room has to be allowed. For example, the charter party can add a clause saying "14days more or less in charterer's option" or something similar to this. The market is of vital importance regarding the choice, made by the charterer, to return as soon as possible or as late as possible.

The charterer should use the ship for its missions in the determined period. If the charterer cannot use the ship, because of breakdown or other delays the owner is responsible. The ship will appear in "off hire" and then the charterer does not pay freight until the ship is operating again. Bunkers, which are consumed in an "off hire" situation, have to be paid by the owner. The off hire period is not added in the charter party unless expressively agreed.

Usually the time of return will be noted. The owner will be very interested in this in order to plan further activities for the ship. At return a **Redelivery Certificate** is signed which will note the time, date and remaining bunkers at delivery.

When the charterer has kept the ship beyond the reasonable agreed time, it is called "overlap". When overlap occurs the owner can claim market freight for the time lost, if the market freight is higher than the time freight. In extremely late re-deliveries, compensation can be claimed, if the charterer causes cancelled business, which would have earned profit above the market level.

If not specially determined, the time freight is due to be paid in advance, as soon as the ship is delivered on time in the right place, and fully equipped according to the charter party. The payment is usually in advance, monthly or in 14 days termin.

If the captain is instructed not to sign the Bill of Lading, this is a successful way to pressure an unwillingly charterer. Therefore it is especially important to examine the time charterer's financial capacity in long-term charter parties. A middle sized or middle solid charterer can be influenced to get a bank guarantee, i.e. for 4 months freight in advance.

Upon re-delivery, the ship should be in the same condition as at the delivering time, except from the usual, normal fair wear and tear. With this I hope you have got some understanding of a time charter party.

4.6 CONTRACT OF AFREIGHTMENT (COA)

The third charter form is the freight contract (transport contract) or the quantity contract which is almost similar to the voyage charter party. This is a contract for the transport of large quantities of oil, ore, grain, etc. over an agreed period of time. During such a transport contract the owner company is not obliged to use a special ship, but the owner accepts to make a suitable ship available, within the limits of responsibility drawn in the contract. The charterer is obligated to deliver the cargo.

The afreightment contract is usually an agreement between owners of big quantity cargo and transport companies as big ship owners. The advantage for a charterer is the covering of the shipping program with only one company or group, and in this way he avoids having to find a charter for every shipment. He knows that in the contracting period, when selling the cargo, what the freighting element will be. Furthermore, the charterer can, in some situations, negotiate a freight contract in a time when he expects the future rate to rise.

The ship owner however may believe that the activity in the market is sinking, and can in this way secure himself against down periods. He can go in the market and include tonnage in time charters or voyage charters at a lower freight than he himself receives and be compensated by the difference in income, if he is short of tonnage.

The afreighting contracts are often valid for a rather long period of time and large quantities. An example, 1.000.000.- tonnes oil pr year in a period of 2 years. It is easy to realise that in a long-term transport contract many unforeseen situations may occur and the common procedure is, therefore, to make clauses in the contract to protect against these unforeseen situations.

So a freight contract stipulates no special ship and the owner can freely use any suitable ship to execute the transport mission.

Usually the loading dates are determined within certain marginal (windows) and then it is important to follow these and the determined quantity accurately. In addition, it is especially important to obey the reporting regulations at all times.

Every single voyage, under a COA (Contract of Afreightment), is provided with the regulations commonly found in a voyage charter party. Very often the shipments are carried out regularly through the time period (fairly spread out), but occasionally the activity in shipments vary with the season, etc.

4.7 DEMISE CHARTER

The fourth charter form is demise charter. This form of charter lets the charterer rent the whole ship from the company. Demise charters is, for example, where the renting contract says the charterer shall pay all expenses concerning, crew payments, maintenance and all running expenses.

Just as in the time charter, the freight is pre-payable per month in a demise charter. The charterer uses the ship in the chartered period as if he is the owner and pays all expenses and maintenance in the period including the crew expenses. The crew is hired by charterer and employed by charterer and not by the owner. In juridical sense a demise charter is an owner.

Occasionally, the company reserves the right to insure the ship or at least the charterer. If the charterer will arrange this before hand, then the terms must be accepted regarding the insurance amount and the conditions. The company has to make sure that the demise charter insures the ship responsibly and with a first class insurance company.
Usually only the owner will pay the capital expenditures relating to the ship, but other arrangements can be made. Some times the charterer reserves the right to have some of their own senior officers on board the ship. The expenses connected to this are agreed to before hand.
The demise charter is usually a long-term contract, and often in combination with special finance and sales contracts. Often the charterer has an option to buy the ship at the end of the charter party period. In other cases, it can be agreed that at the end of the charter party period, the ownership passes to the demise charter.
With the demise charter, the demise charterer has bought the ship, paying the freight in monthly terms. This has two elements - a freight element and a buying element, which is already included in the monthly hire.
Now the charter party forms are viewed, and here we choose to enlighten you on the word "Seaworthiness" as a conclusive and very important part of negotiated contracts.

4.7.1 Seaworthiness

The owner is obligated to make a completely seaworthy ship available, if nothing else is noted. Seaworthiness cover many areas we do not have in mind daily. The following will illustrate "seaworthiness":

- **(Cargo-worthiness) the ship is able to receive cargo at determined date and time**
- **Sufficient amount of bunkers, and quality**
- **Load/discharge equipment should be operative**
- **Authority Regulations and Classification companies must be satisfied**
- **Complete and fully qualified crew**
- **No heating coil leakage, or leakage between cargo tanks**
- **Seaworthy at the departure load/discharging ports**

If the charterer discovers lack of seaworthiness before a voyage he can demand this to be improved within reasonable time, or in the worst case, cancel the contract. When the voyage is started and lack of seaworthiness is discovered, the charterer can not cancel the contract, but will then claim compensation for losses due to the lack of seaworthiness. Still the assumption of delivering cargo from the charterer is that the ship is seaworthy.

4.7.2 Cargo samples

Make sure that samples are taken of the cargo. This is important, in case of requests later on concerning the quality of the loaded oil. Keep samples as evidence, and be prepared in case claims from the receiver should eventually come. The samples should be kept on board at least 12 months. Usually, samples of the cargo are delivered on board and then to be handed over to the receiver of the cargo. Be quite sure that the samples are representative of the actual cargo, before you sign any receipt approving the samples. (For receipt only).

4.7.3 Frozen in

If the ship is icebound because of the charter's orders to lay in this specific port, the charterer pays the time loss.

4.7.4 Maintenance

The owner of the vessel pays for classification, etc., all maintenance like docking period and if the ship goes off-hire.

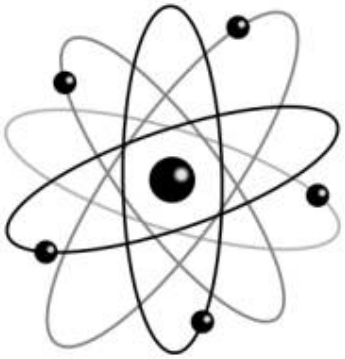
05- Chemistry And Physics

BASIC ORGANIC CHEMISTRY

Organic chemistry mostly deals with chemical compounds containing carbon.

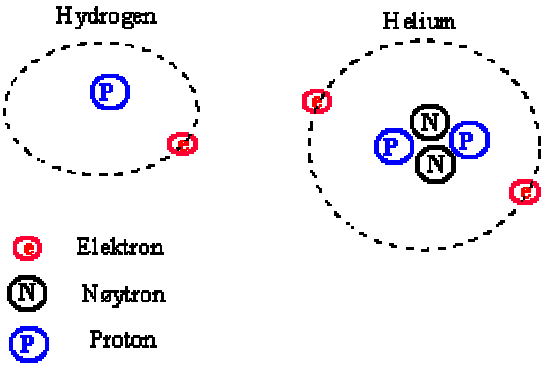
5.1 THE PERIODIC SYSTEM

The periodic system is built on the principle that the electrons in the outer shell determine the chemical properties of a material. An atom consists of **protons**, **neutrons** and **electrons**. Protons and electrons form the **atomic nucleus**. The electrons move with high velocity around the nucleus, at different levels and orbital. The levels are numbered from K to Q and called **electron shells**. At maximum, there can be 8 electrons in the outer shell. There are equal numbers of protons as electrons in an atom, meanwhile the number of neutrons may vary.

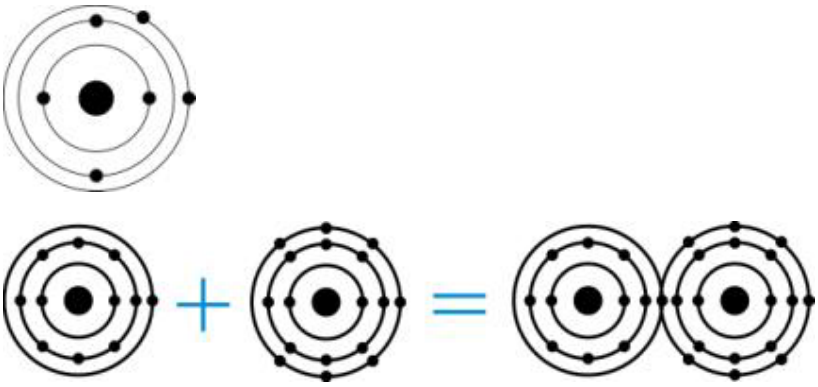


The periodic table arranges the 106 elements in increasing number of electron shells. Each vertical column is one of the periodic table's **main groups**. The number of electrons in the outer shell is always equal to the atom's main group number. Two of the main elements in the periodic system are Hydrogen and Helium, and fall under group IA and VIIA. The atomic models are illustrated as follows:

Carbon falls under group IVA and has 4 electrons in the outer shell.



The elements in the group IA have only one electron in the outer shell.



It is therefore easy to emit one electron to elements within group VIIA, which has seven electrons in the outer shell and is "short of" one electron to fill up the outer shell. Such mutual sharing of an electron is called **ion bonding**. An example for such a bonding is when Sodium (Na) and Chlorine (Cl) bond with one another and form Sodium chloride or cooking salt.

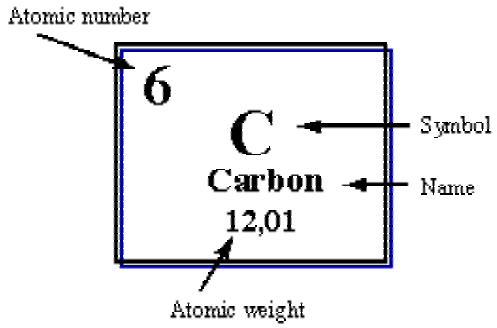
$Na + Cl \longrightarrow Na^+ + Cl^- \longrightarrow NaCl$

Sodium "emits" the only electron to Chlorine, and is thereby positively charged. Chlorine "receives" the electron and is thereby negatively charged. We call this mutual sharing of electrons, **covalent bonding**. Covalent bonding is common in both organic and inorganic chemical reactions. When two or more atoms bond together, they form a **molecule**.

There are 8 **side groups** between the main groups IA and IIA. All the elements in the side groups are metals, and they easily form alloys with one another.

The rows in the periodic chart indicate the **periods**. The 7 periods indicate the number of electron shells. Sulphur is located in row 3 (period number 3) and has thereby 3 shells. We also look at the electron shells as the electrons' energy level.

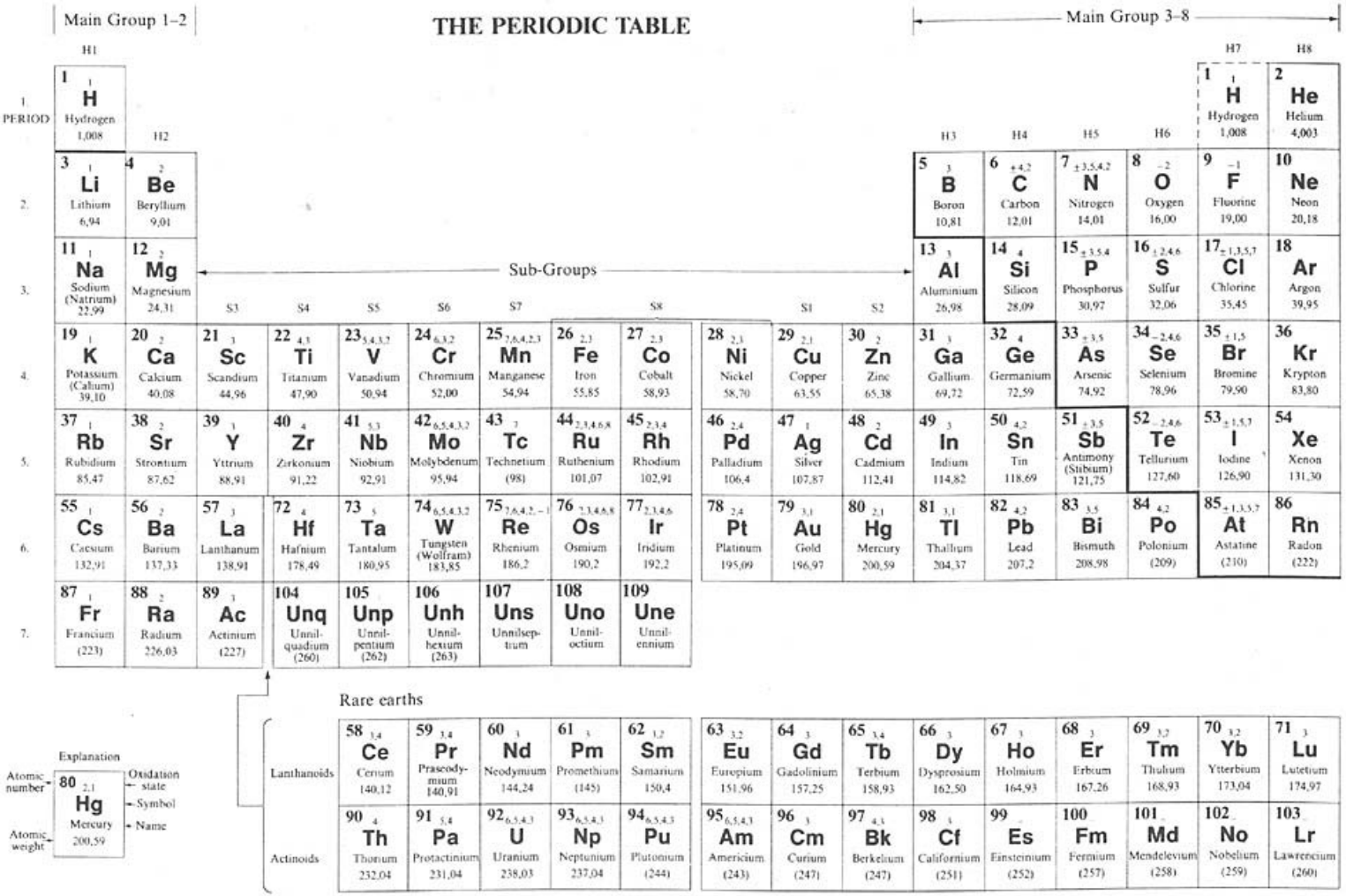
The elements in group VIIA are named **noble gases**. Noble gases occur only in atomic form.



Most inorganic elements are metals. The metals form metal bonding where the atomic are organised close together.

The individual element has numbers from 1 to 106. The periodic system's number is the element's **atomic number**. The atomic number also indicates the total number of electrons in the atom.

THE PERIODIC TABLE


Main Group 1–2
Main Group 3–8
Sub-Groups
H1
H2
H3
H4
H5
H6
H7
H8
S1
S2
S3
S4
S5
S6
S7
S8
PERIOD
1.
2.
3.
4.
5.
6.
7.
1 1 H Hydrogen 1,008
2 He Helium 4,003
3 1 Li Lithium 6,94
4 2 Be Beryllium 9,01
5 3 B Boron 10,81
6 +4,2 C Carbon 12,01
7 ±3,5,4,2 N Nitrogen 14,01
8 −2 O Oxygen 16,00
9 −1 F Fluorine 19,00
10 Ne Neon 20,18
11 1 Na Sodium (Natrium) 22,99
12 2 Mg Magnesium 24,31
13 3 Al Aluminium 26,98
14 4 Si Silicon 28,09
15 ±3,5,4 P Phosphorus 30,97
16 ±2,4,6 S Sulfur 32,06
17 ±1,3,5,7 Cl Chlorine 35,45
18 Ar Argon 39,95
19 1 K Potassium (Calium) 39,10
20 2 Ca Calcium 40,08
21 3 Sc Scandium 44,96
22 4,3 Ti Titanium 47,90
23 5,4,3,2 V Vanadium 50,94
24 6,3,2 Cr Chromium 52,00
25 7,6,4,2,3 Mn Manganese 54,94
26 2,3 Fe Iron 55,85
27 2,3 Co Cobalt 58,93
28 2,3 Ni Nickel 58,70
29 2,1 Cu Copper 63,55
30 2 Zn Zinc 65,38
31 3 Ga Gallium 69,72
32 4 Ge Germanium 72,59
33 ±3,5 As Arsenic 74,92
34 −2,4,6 Se Selenium 78,96
35 ±1,5 Br Bromine 79,90
36 Kr Krypton 83,80
37 1 Rb Rubidium 85,47
38 2 Sr Strontium 87,62
39 3 Y Yttrium 88,91
40 4 Zr Zirkonium 91,22
41 5,3 Nb Niobium 92,91
42 6,5,4,3,2 Mo Molybdenum 95,94
43 7 Tc Technetium (98)
44 2,3,4,6,8 Ru Ruthenium 101,07
45 2,3,4 Rh Rhodium 102,91
46 2,4 Pd Palladium 106,4
47 1 Ag Silver 107,87
48 2 Cd Cadmium 112,41
49 3 In Indium 114,82
50 4,2 Sn Tin 118,69
51 ±3,5 Sb Antimony (Stibium) 121,75
52 −2,4,6 Te Tellurium 127,60
53 ±1,5,7 I Iodine 126,90
54 Xe Xenon 131,30
55 1 Cs Cæsium 132,91
56 2 Ba Barium 137,33
57 3 La Lanthanum 138,91
72 4 Hf Hafnium 178,49
73 5 Ta Tantalum 180,95
74 6,5,4,3,2 W Tungsten (Wolfram) 183,85
75 7,6,4,2,−1 Re Rhenium 186,2
76 2,3,4,6,8 Os Osmium 190,2
77 2,3,4,6 Ir Iridium 192,2
78 2,4 Pt Platinum 195,09
79 3,1 Au Gold 196,97
80 2,1 Hg Mercury 200,59
81 3,1 Tl Thallium 204,37
82 4,2 Pb Lead 207,2
83 3,5 Bi Bismuth 208,98
84 4,2 Po Polonium (209)
85 ±1,3,5,7 At Astatine (210)
86 Rn Radon (222)
87 1 Fr Francium (223)
88 2 Ra Radium 226,03
89 3 Ac Actinium (227)
104 Unq Unnil-quadium (260)
105 Unp Unnil-pentium (262)
106 Unh Unnil-hexium (263)
107 Uns Unnilsep-tium
108 Uno Unnil-octium
109 Une Unnil-ennium
Rare earths
Lanthanoids
Actinoids
58 3,4 Ce Cerium 140,12
59 3,4 Pr Praseody-mium 140,91
60 3 Nd Neodymium 144,24
61 3 Pm Promethium (145)
62 3,2 Sm Samarium 150,4
63 3,2 Eu Europium 151,96
64 3 Gd Gadolinium 157,25
65 3,4 Tb Terbium 158,93
66 3 Dy Dysprosium 162,50
67 3 Ho Holmium 164,93
68 3 Er Erbium 167,26
69 3,2 Tm Thulium 168,93
70 3,2 Yb Ytterbium 173,04
71 3 Lu Lutetium 174,97
90 4 Th Thorium 232,04
91 5,4 Pa Protactinium 231,04
92 6,5,4,3 U Uranium 238,03
93 6,5,4,3 Np Neptunium 237,04
94 6,5,4,3 Pu Plutonium (244)
95 6,5,4,3 Am Americium (243)
96 3 Cm Curium (247)
97 4,3 Bk Berkelium (247)
98 3 Cf Californium (251)
99 Es Einsteinium (252)
100 Fm Fermium (257)
101 Md Mendelevium (258)
102 No Nobelium (259)
103 Lr Lawrencium (260)
Explanation
Atomic number
Atomic weight
80 2,1 Hg Mercury 200,59
Oxidation state
Symbol
Name

5.1.1 Carbon

You find the element Carbon in the main group IVA/period number 2, which has four electrons in the outer shell number 2. The atomic number for carbon is 6, which means there are totally 6 electrons divided between two electron shells with 4 electrons in the outer shell, and 2 electrons in the innermost.
There are many isotopes of carbon. Isotopes have the same number of protons, but different number of neutron in the atomic nucleus. There are two natural forms of Carbon, graphite and diamond. Carbon is not particular reactive in room temperature. When heated, it will easily react with for example, Oxygen. We say that carbon is combustible. The different products of the combustion are dependent of accent to oxygen.

$C + O_2$ $= CO_2 + 393$ kJ (at complete combustion)
$C + 0{,}5\ O_2$ $= CO + 113$ kJ (at incomplete combustion)

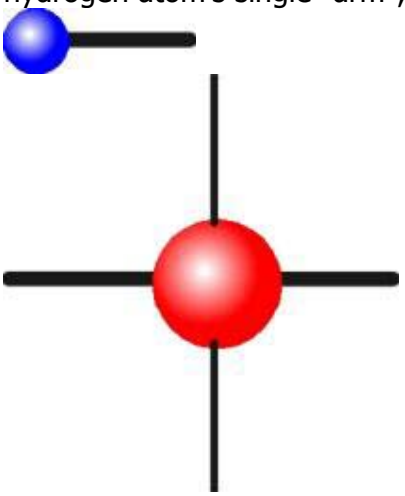
Both reactions are exothermic, that means heat is produced in the chemical reaction. Both reaction products are also gases. Carbon dioxide, CO_2, is the product of complete combustion of carbon and **carbon monoxide**, CO, which is the product of incomplete combustion of carbon.
A partly incomplete combustion produces both less heat and more formation of carbon monoxide than a complete combustion. Carbon monoxide is odorless and a very poisonous gas that always is present in a real combustion process. Inert gas produced in an inert gas generator or flue gas plant onboard will always contain carbon monoxide due to incomplete combustion, especially when the air excess is reduced.
Poisoning of carbon monoxide occurs because the hemoglobin in the blood reacts much easier with CO than with oxygen. When you breathe a mixture of these two gases, CO is thereby first absorbed in the blood and seizes the absorption of oxygen. The result of this poisoning is a sort of suffocation at very low concentrations. These relations are very important to notice. You must always check the cargo tank atmosphere for carbon monoxide before personnel are allowed to enter the tank.

5.2 HYDROCARBON GROUPS

Hydrocarbon is a common expression for all chemical compounds that includes carbon and hydrogen.
You find the element carbon in only two different natural conditions, as graphite and as diamond. Carbon is the element that naturally forms most natural chemical compounds. It is not reactive in room temperature, but it will when heated up react more easily with, for example, the oxygen in air. We say that the carbon is combustible. The combustion is exothermic, which is a reaction that produces heat.
Hydrogen is the smallest main element. The gas (H_2), is light and is flammable in air. There are small quantities of hydrogen in free natural form on earth. Hydrogen is strongly widespread, first of all in form of water and naturally compounds together with carbon. Crude oil and natural gas consist mainly of a mixture with various unequal hydrocarbon compounds. Following sketch indicates an example of a natural gas' composition:

<table>
<tr><td rowspan="4">Natural gas from wells</td><td rowspan="3">Hydro carbons</td><td>Gas</td><td>Methane</td><td>LNG</td></tr>
<tr><td>(NLG)</td><td>Ethane
Propane
Butane</td><td>LPG</td></tr>
<tr><td>Heavy fractions min 5 C-atoms</td><td colspan="2">Naphta
Natural gasoline and other</td></tr>
<tr><td>Non-hydro -carbons</td><td colspan="3">Water, carbon dioxide etc.</td></tr>
</table>

Carbon has four electrons in the outer electron shell that can be divided with others. You may look at the four electrons as four "arms" that can connected to the hydrogen atom's single "arm", and creates hydrocarbon compounds.



Some of the hydrocarbon compounds are naturally created; other are only created in chemical controlled processes. To simplify the overview of these natural components, and all new hydrocarbon compounds that is created in the petrochemical industry, the different hydrocarbon compounds are grouped dependent of how the "arms" or the chemical bonding are between the two atoms. The most important hydrocarbon groups are:

- **Alkanes, also called Paraffin's**
- **Alkyls**
- **Alkenes, also called Olefins**
- **Alkynes, also called Acetylides**
- **Alkadienes, also called Di-olefins**
- **Cyclo-alkanes**
- **Arenes**
- **Alcohol**
- **Aldehydes**
- **Ketones**

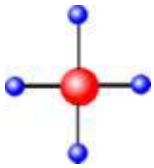
In addition to above listed hydrocarbon groups there are others like Carboxylic acid, Esters, Ethers etc.

5.2.1 Alkanes

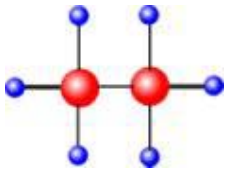
Alkanes are the simplest hydrocarbon compounds and is the major part of crude oil and natural gas. The carbon atom's four arms are united to the hydrogen atoms' single arm and has this general molecule-formula:

$\mathbf{C_nH_{2n+2}}$ where "n" is a positive integer.

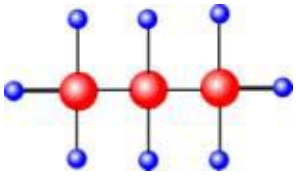
All alkane compounds have the ending "-ane". The gas methane is the smallest molecule, and is the main component in natural gas. A methane molecule consists of one carbon atom and four hydrogen atoms.



By adding one carbon atom and two hydrogen atoms to methane, we get ethane, which is the next component in this group.
By adding carbon atoms and hydrogen atoms, and at the same time maintain the same simple form of binding, new alkanes are formed. The third component in the alkane group is propane, C_3H_8.

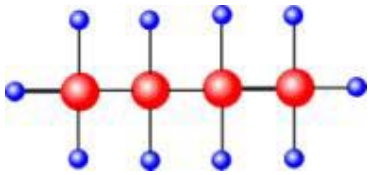


When the number of carbon atoms increase, the number of possible bonding between the atoms increase. You can arrange 20 carbon atoms and 42 hydrogen atoms in 366319 different ways.



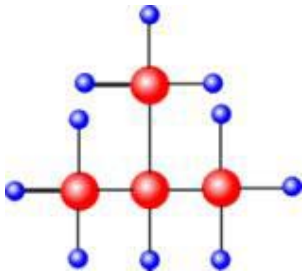
Many materials may have the same molecule formula, but the properties (boiling point, density, etc.) are different because the atom structure is different. Such bonding is called isometric bonding. Normal-butane and iso-butane are examples of isomers where both have the same molecule formula, but different properties.

n-Butane, C_4H_{10}



iso-Butane, C_4H_{10}

Chemical formulas and names are many times derived from each other. Pentane is derived from the Greek word "pent". That means "five", it refers to the number of carbon atoms in the material. Other names like methane and ethane are not following this system. These names are called **trivial names**.



In the following list, some of the most common alkanes are listed with melting- and boiling point at atmospheric pressure. Note that melting point and boiling point increase by the length of chain for the straight-chained hydrocarbons.

Name:	**Formula**	**Melting point °C**	**Boiling point °C**	**Number of isomeric compounds**
Methane	CH_4	-182,5	-161,6	0
Ethane	C_2H_6	-183,2	-88,6	0
Propane	C_3H_8	-189,9	-42,5	0
n-Butane	C_4H_{10}	-135	-0,5	2
iso-Butane	C_4H_{10}	-145	-11,7	
n-Pentane	C_5H_{12}	-130	36	3
n-Hexane	C_6H_{14}	-95	69	5
n-Heptane	C_7H_{16}	-91	98	9
n-Octane	C_8H_{18}	-57	126	18
n-Nonane	C_9H_{20}	-54	151	35
n-Decane	$C_{10}H_{22}$	-30	174	75

5.2.2 Alkyls

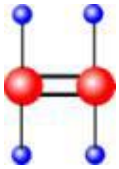
If one hydrogen atom is removed from an alkane molecule, an alkyl molecule is created. The different compounds are named by the alkane, but with the ending "-yl" instead of "-ane".
The general molecule formula for alkyl groups are: $\mathbf{C_nH_{2n+1}}$

The compounds in this group are chemical products where the CH-group is attached to various alcohol and chloride compounds.

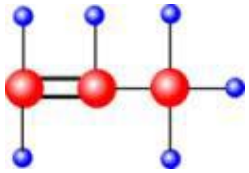
5.2.3 Alkenes

You do not find alkenes in the natural forms. These compounds are produced in a cracking process within the petrochemical industry. Alkenes are hydrocarbons with a double bonding between two of the carbon atoms. The general molecule formula for alkanes is:
$\mathbf{C_nH_{2n}}$

The simplest alkene is ethylene, C_2H_4, that is produced by cracking of for example propane, ethane, butane or naphtha.



The next alkene is propylene, C_3H_6, which is produced by cracking other hydrocarbons or naphtha.
The alkenes are so-called **unsaturated hydrocarbons**. The double bonding may easily loosen up, "arms" that are attached to several hydrogen atoms released, and the alkenes may change back to (chemical reaction) alkanes.

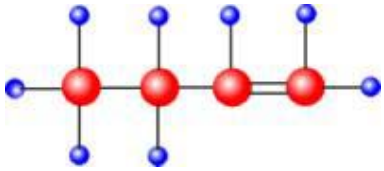


Name:	Formula	Melting point °C	Boiling point °C	Number of isomeric compounds
Ethylene (ethene)	C_2H_4	-169	-103,7	0
Propylene (propene)	C_3H_6	-185,2	-47,7	0
1-Butene	C_4H_8	-185,4	-6,3	4
cis-2-Butene	C_4H_8	-138,9	3,7	4

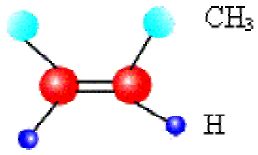
trans-2-Butene	C_4H_8	-105,6	0,9	4
iso-Butene	C_4H_8	-140,4	-6,9	4
1-Pentene	C_5H_{10}			6

The number of isomeric compounds increase by the number of carbon atoms. Double bonding also gives additional possibilities for combination because the double bonding may be located on several different places inside the molecule. The following molecules have the same molecule formula, but different structure and thereby different properties. Notice the difference between a cis-bonding and a trans-bonding.

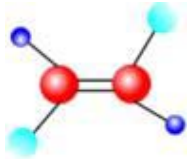
1-Butene



Cis-2-Butene



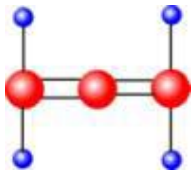
Trans-2-Butene



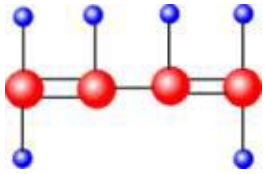
5.2.4 Alkadienes

Alkadienes are hydrocarbons with two doubles bonding in the molecule. The general molecule formula for alkadienes is:

C_nH_{2n-2}



Propadiene



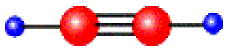
1,3 Butadiene

Name:	Formula	Melting point °C	Boiling point °C	Number of isomeric compounds
Propadiene	C_3H_4	-136,5	-34,5	0
1,3-Butadiene	C_4H_6	-108,9	-4,4	

5.2.5 Alkynes

Alkynes are hydrocarbons with **a triple bonding** between two carbon molecules. The alkynes have the same general formula as for the alkadienes:

C_nH_{2n-2}



Alkynes are unsaturated hydrocarbons, and form a homologous serial. The simplest compound within this group is etyne, C_2H_2.

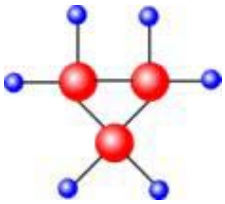
Name:	Formula	Melting point °C	Boiling point °C	Number of isomeric compounds
Etyne (Acetylene)	C_2H_2	-82	-84	0
Propyne (Allyene)	C_3H_4	-102	-23	0

5.2.6 Cyclo alkanes

Cyclo alkanes are hydrocarbons with single bonding between the carbon atoms, but the molecules form a circular structure. The compounds are saturated, and form a homologous serial. The general molecule formula for the cyclo alkanes is;

C_nH_{2n}

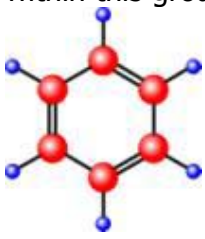
The circular structure of the cyclo propane:



Name:	Formula	Melting point °C	Boiling point °C	Number of isomeric compounds
Cyclopropane	C_3H_6	-126	-34	
Cyclobutane	C_4H_8	-50	13	
Cyclopentane	C_5H_{10}	-93	50	
Cycloheptane	C_6H_{12}	6	81	

5.2.7 Arenes

Arenes are cyclic, but unsaturated hydrocarbons because of its double bonding. The compounds are aromatic. Benzene, which is very stabile and frequently used together with other products in the petrochemical industry, is a well-known product within this group.



Name:	Formula	Melting point °C	Boiling point °C	Number of isomeric compounds
Benzene	C_6H_6	5,5	80,1	

5.2.8 Alcohol's

Alcohol are organic compounds where the functional group is the hydroxyl-group –OH. All alcohol ends with "-ol". The different alcohol's are divided in subgroups, dependent of the form of bonding.

Name:	Formula	Melting point °C	Boiling point °C	Number of isomeric compound
Methanol	CH_3OH	-97,8	64,5	
Ethanol	C_2H_5OH	-117,3	78,3	

5.2.9 Aldehydes

Aldehydes have one functional group –CHO.

Name:	Formula	Melting point °C	Boiling point °C	Number of isomeric compound
Formaldehyde	HCHO	-118	-19	
Acetaldehyde	CH_3COH	-123,5	20,2	

5.2.10 Ketones

Ketones are compounds where the functional group is the carbon-group.

Name:	Formula	Melting point °C	Boiling point °C	Number of isomeric compound
Acetone	CH_3COCH_3	-94,3	56,2	

5.3 CHEMICAL REACTIONS

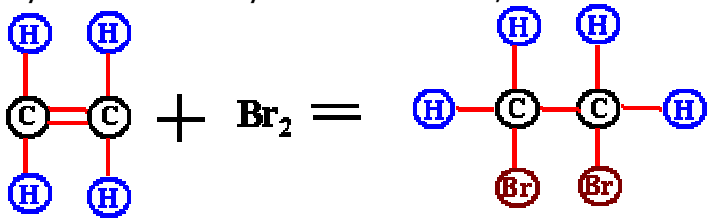
New products are continuously made in the petrochemical industry by allowing hydrocarbon compounds participate in chemical processes and reactions.

5.3.1 Unsaturated chemicals

Unsaturated chemical compounds contain one or several double or triple bonding between the carbon atoms. They can easily saturate the vacant valences in a chemical reaction. A chemical reaction may take place:

- **by mixing unsaturated compounds with another product.**
- **by increasing the temperature and pressure in the chemical compound, alone or together with other compounds.**

To visualize an unsaturated compound, a solvent bromine and water can be used. If you mix bromine (Br) with a saturated oil, the bromine-coloured water will disappear, because the double bonding is opened and bromine appear in every vacant valence. A chemical reaction has appeared between two compounds, and a new compound is created.
If you combine ethylene and bromine, this chemical reaction will take place:



When unsaturated chemical compounds are heated under pressure, the molecules react with each other and form large molecules, so-called macromolecules. This is called **polymerisation**. To start the reactions or to increase the velocity of reaction, a catalyst is often used. A catalyst is a material that increases the velocity of reaction in a chemical process without changing its own state.
Linear polyethylene is a plastic raw material, which is a **polymer** of ethylene produced by polymerising ethylene with a **peroxide** catalyst. Benzol peroxide is an example of peroxide used as a catalyst for production of polyethylene.
Other types of polymers are made of ethylene or together with other hydrocarbon. The properties are different, and the plastic raw materials are used alone or together with others when producing plastic products.
Most plastic raw materials are produced like this. Molecules or mixture of molecules which is capable of polymerise, are called **monomers**. The number of monomers taking part of a polymerisation may be many thousand. A linear polyethylene has a molecular weight of more than 6000, others are considerably smaller. The molecular weight is controlled by temperature, concentration of catalyst or amount of ethylene.

It is not only the unsaturated hydrocarbon compound that may polymerise. In 1907, Baekeland managed to control three-step polymerising with phenol and formaldehyde. The product "Bakelite" was the first synthetic polymer that was produced, and has great significance even today**.**

The following list demonstrates some of the most common plastic materials today, and how they are produced:

Polymer	**Monomer:**	**Polymerisation:**
Polyethylene	$(CH_2)_n$	Ethylene
Polytetrafluorethylene (PTFE)	$(C_2F_4)_n$	Tetrafluorethylene
Polyvinylcloride (PVC)	$(H_2CCHF)_x$	Vinylcloride
Polypropylene	$(C_3H_5)_n$	Propylene
Polystyrene	$(C_6H_5CHCH_2)_n$	Styrene monomer

5.3.2 Peroxides and inhibitors

Peroxides are highly explosive, and can form into unsaturated compounds, as for example butadiene and VCM if oxygen is present. They can appear as powder in pipes and tanks and are very unstable and can easily explode. The formation of peroxides in butadiene can entail polymerising with powerful heat generation.
To avoid such a chemical reaction, the content of oxygen in the tank atmosphere is kept as low as possible.
To assure that all oxygen is removed, an **inhibitor** is added to the individual cargo. An inhibitor is a material that itself, in low concentrations, reacts with the oxygen. Some types of inhibitors have the capability to react with radicals so that the velocity of reaction reduces or to cease up. Most inhibitors are very dangerous to our health, and must therefore, be handled with the utmost care.
1,3 Butadiene and VCM are examples of cargo that are added inhibitors. Approximately 5 ppm hydroquinon is added to VCM to prevent polymerisation. US Coast Guard requires that one add 100 ppm TBC (Tertiary Butyl Catechol) to 1,3 butadiene to prevent a polymerisation with strong heat generation.
Humidity and water will reduce the effect of inhibitors, in some cases water will accelerate a chemical reaction.
Cargo that is inhibited must have a certificate with:

- name and amount
- inhibitor date and for how long the inhibitor is efficient
- precautions, if the voyage lasts longer than the effect of the inhibitor
- eventual temperature limitation

The above mentioned inhibitors are only present in the liquid phase. In all probability, dangerous peroxides will be formed inside the lines of the cooling plant's "condensate" system. It is recommended that these parts of the system are checked regularly, when the inhibited cargo is cooled. Further, it is recommended to circulate some inhibited liquid through the part of the system where "condensates" remains without the inhibitor.

Introductorily, we have said that polymerising can occur if the temperature is high enough. The following restriction of maximum outlet temperatures from the compressor is required:

- **maximum 60 ^{o}C for butadiene**
- **maximum 90 ^{o}C for VCM**

5.3.3 Reaction with other cargo and materials

Some cargo can react strongly with other cargo. This makes great demands for cleaning, before loading and full segregation against other cargo. Whenever cargo segregation is required, spool pieces must be used. It is important that all materials are compatible with which the cargo can come in contact. The material must, for example, in **all** gaskets that can be in contact with propylene oxide be of PTFE or a similar **approved** material type.

5.4 TEMPERATURE, HEAT, ENERGY AND PRESSURE

When you mix cold and warm water, the temperature will eventually be a specific average temperature. If multiple objects, with different temperature, are placed in a room, the temperature of the objects and the temperature in the room will eventually be the same. This is the heat theory's O. law that forms the basis for measuring the temperature with a thermometer.

Empirically, the heat will, at all times, move from the warmer material to a colder material. One can prevent heat transmission by a heat-insulating barrier. If the barrier is totally heat insulated, it is called adiabatic. If a material, or a collection of materials (a system), is totally surrounded by adiabatic barriers, no heat exchanging can occur with the surroundings.

The temperature characterises a fixed stated condition of a material, and can only be measured indirectly by measuring another directly measurable size, that changes with the temperature. With a mercury thermometer or an alcoholic thermometer, the temperature can be determined from how the liquid changes the volume.

Because of this, the individual materials change the volume differently at varying temperatures. Graduation on a mercury thermometer must necessarily be different from the graduation of an alcohol thermometer. One calibrates thermometers by measuring the temperature at one or several fixture points. Boiling water at 760 mm HG is one example of such a fixture point.

Measuring the temperature based on other material's characteristics has its obvious weaknesses. Different temperature scales make its impossible to establish a uniform method of many thermal calculations.

William Thompson, later ennobled as Lord Kelvin, was one of many physicists that worked to find an absolute temperature scale independent of another material's properties. He defined a theoretical temperature scale, which later acquired the name "Kelvin" (or K).

The Kelvin scale, adopted by the SI-system, begins at the absolute zero point, which is defined to –273,15^{o}C, but has the same graduation as the Celsius-scale. In most thermal calculations, it is sufficient to estimate the zero point of the Kelvin scale at –273^{o}C, which will be used as conversion factor in this compendium.

A temperature difference has the same measured value in Kelvin as in the Celsius-scale. Converting from Celsius to Kelvin is:

Temperature in Kelvin $\Rightarrow$ 273 + temperature in Celsius degrees

- 50^{o}C	= (273 + (-50))K	= 223 K
0^{o}C	= (273 + 0)K	= 273 K
+50^{o}C	= (273 + 50)K	= 323 K

When a car decelerates, the velocity of the car delerates, the kinetic energy is reduced. The temperature on the brakes rises simultaneously. An electric driven compressor, which compresses the gas, increases the temperature of the gas, but consumes electrical power simultaneously. If we switch on the hotplate, the temperature rises, simultaneously the hotplate consumes electrical energy. When oil burns, chemical combined energy falls as the temperature rises. Mutually, for all these phenomena is that a temperature increase is in progress simultaneously as we copy energy in one or another form. Mechanical energy, electrical energy, chemical energy, or heating energy, are all expressions for energy that can be summarised as:

"Energy is the capability to perform work"

We will mainly go into two forms of energy in this compendium, potential (position) energy and kinetic energy.
A temperature increase can take place by transfer of heat from one material to another at lower temperature. It is natural to conclude that heat transfer is also a form of energy transfer. Heat is often defined as the energy that is transferred from one system to another, because of difference in temperature. We measure heat with the same unit as all other forms of energy.
The heat (quantity) required to heat up one gram of water one degree Celsius at a temperature of 14,5^{o}C, is defined as one calorie (cal).
The SI-system uses the unit "Joule" for heat. If 41855 Joule is supplied to 1 kg water at a temperature of 14,5^{o}C, the temperature will rise 1K.
Conversion between the units calorie (cal) and Joule (J) is therefore;

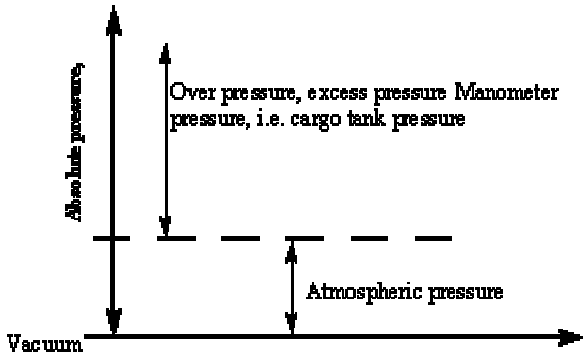
1 cal = 4,1855 J or 1 kcal = 4185,5 J

One can transfer heat from one place to another in different methods. If an iron bar is heated at one end, the whole bar will gradually be warm. The heat will spread through the material and we say that the heat occurs as **stationary thermal-conductance**.

At thermal conducting, the heat is, at all times, deducting from a location with higher temperature to a location with lower temperature. The speed of the thermal conductance is a temporary dependent of the material. Metals are good heat conductors, gases the inferior.

Stationary thermal conductance or heat flow through one level is defined as:
F = **l/d** x **A** x **(T_1 - T_2)** where:

l = specific thermal conducting ability or thermal conductivity with unit W/mK
δ = the thickness of the material in m
A = the area of the material in m^2
T_1 = temperature on the warmest side in Kelvin
T_2 = temperature of the coldest side in Kelvin
General expressions for heat flow, heat quantity, work or energy is always with the SI-unit **J** (Joule). When above mentioned energy forms are measured or calculated during a stated period, the measuring unit is always in **J**/**s**, which is the same as **Watt (W)**.
In liquid and gases, the molecules move by heat conductance. The heat alters the density, and different density provokes flow that takes the heat ahead. When heat conductance takes place by movement in the material, we say that the heat is transferred by convection.
Heat can also be transferred by radiation. In the vicinity of a heated material in cold surroundings, one can feel the heat at a long range. We say that the material radiates heat or emits heat rays. You can not lead the heat you feel through the air, because as you hold a shield against the heat source, the heat is gone.
To produce heat from radiation, you have to stop it with a material. The radiate is slightly enervated in air. The faster and darker the material is, the easier the radiate absorbs and converts to heat. The influence of heat radiation is often underestimated. Understanding this type of heat transfer is important in the work of reducing heat transfer.
Emission or emanation is also a form of radiation. A practical example is in a thermos. Double walls with vacuum alone does not prevent transfer of products, in spite of fact that thermal conductance in vacuum is zero. Some heat is transferred by radiation between walls. To eliminate this, the sides that face into vacuum are silvered. This reduces the heat radiation to a few percent.
You can express the relation between absorption and emission as the absorption capability of two materials that has to conduct to each other as emission capabilities.
One measures and describes pressure in different ways independent of what is measured, who measures it and how it is measured. The engineer reads the pressure in a system on a manometer. The mate reads the atmospheric pressure on a barometer or a mercury column. In thermal technical charts and diagrams, the expression absolute pressure is used.



One can easily describe the different "pressure" by help of a diagram. The lowest possible pressure that can exist is vacuum. Therefore one estimate absolute pressure from this starting point. The pressure of the manometer is pressure above the atmospheric pressure. As the atmospheric pressure will vary, the logical choice is to show pressure dependent values as a function of absolute pressure, like for example in thermal technical charts and diagrams.
On can use a mercury column or a water column, both to indicate atmospheric pressure and excess pressure. A normal atmospheric pressure is defined as 760 mm Hg.

The gravity of or the pressure that a liquid column of 760 mm Hg amounts to can be calculated in this way:

p = r x g x H where:
p= pressure in N/m^2 (Newton per square meter)
r= the density of liquid (The density of mercury 13595,1 kg/m^3
g= the gravity of shaft ration (9,81 m/s^2)
H= height of the liquid column in meter (760 mm = 0,76 meter)

p = (13595,1 x 9,81 x 0,76)N/m^2 = <u>101359 N/m^2</u>

1 normal atmospheric pressure define as = 1013 mill bars

1 atmosphere = 10^5 N/m^2 = 100 000 Pa = 100 kPa = 1 bar

5.5 OIL PHYSICS – AGGREGATE CONDITIONS

History

Back in the antiquity, about 2500 years ago, oil was mentioned in scripts from Asia. The scriptures describe hot springs and that oil lamps were known and in use. However, centuries went by before the oil was in common use. As a matter of fact danger of fire was one reason which prevented utilisation of oil. In USA, which today is rich in oil sources, did not take the oils in common use until the midst of the last century. At first the oils were used in medical treatment then to heal such as rheumatism and pneumonia.

The first well was drilled in USA in 1859 and supplied 1500 litres oil every 24 hours. The oil consumption and development increased dramatically from this time on. John D. Rockefeller founded the «Standard Oil Company» in 1870. The Dutch « Royal Dutch Oil Company» was founded in 1890. In 1909, the English founded «Anglo-Iranian Oil Company». This development has continued up to this day where these companies operate around the world. The need for oil increased at the same speed as the oil discoveries increased. At the same time, knowledge about oil's nature, physics and chemistry improved.

5.5.1 The Oil Transportation

As a start, the oil was transported in barrels by ordinary liners. The oil tankers today were first used at the end of the last century. These tankers have since then changed dramatically through a radical process up to today's technically advanced tankers. Due to the world's oil demand, tank tonnage has increased enormously, along with the average size of ships.

The personnel (crew) operating the ships provide a wide range of knowledge regarding ship operations and its specific cargo. To be an educated and qualified "Ship Officer", it is necessary to have a basic theoretical knowledge and a lot of practical experience on board the ships. In this part of the compendium, the oil's physical properties are reviewed.

Physics is the learning of different substances and property forces and their energy form.

Chemistry is the learning of the substance's composition and the substantial or permanent changes these substances may under go.

The theory about atoms and molecules understands that substances are able to divide into smaller parts, atoms and molecules.

5.5.2 Aggregate States

Solid, fluid and gas form conditions must be seen in connection with the understanding of molecule forces. An example:

When splitting a piece of wood the molecules separate along the split area. The force being used corresponds with the force binding the molecules together. If you now wish to force the two pieces together again, a certain power has to be used. The first power in use will be called the force of cohesion. The second power in use will be called the force of expansion. Cohesion and expansion summed, is called intermolecular force.

The cohesion is due to the fact that all substances (elements), including the smallest parts in a substance, execute a mutual back sweep on each other. We therefore have the same nature as the force of gravity. It decreases rapidly when the distance between the smallest parts increases.
The expansion is due to the fact that the molecules in all substances, both solid, fluid and gas forms execute movements or vibrations and therefore fill-up an entire room.

5.5.3 Solid Substances

A solid substance has a fixed form and fixed volume. An iron bar is resists being lengthened or pressed together. The molecules in the iron bar will try hard to keep a certain mutual distance to each other. The iron bar is resistant to rubbing and bending. In solid substances the molecules have fixed places according to each other, and the same applies to the substance's volume and form. This is because the cohesion and expansive force is very large.

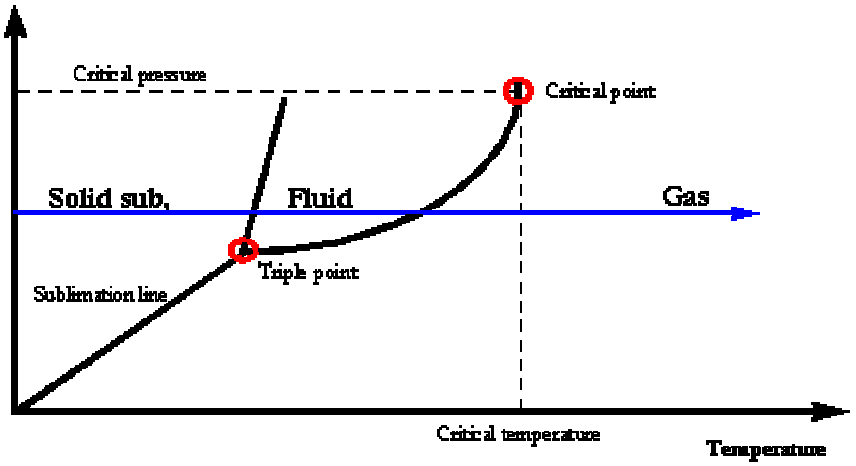
5.5.4 Fluids

Fluids have a fixed volume, but do not have any fixed form. To squeeze water in a cylinder with tight-fitting piston is hard without using large power. Similar to the molecules in solid substances, the molecules in a liquid substance have a certain mutual distance between each other. The liquid molecules on the other hand have no fixed positions according to each other. Liquid will always be shaped based on where the liquid is stored. The cohesion force in liquids is not powerful enough to prevent the molecules from moving freely according to each other. However, the force is still strong enough to maintain the distance between each of the fixed molecules. The expansion force is equal as in solid substances.

5.5.5 Gases

Gases have no fixed volume or fixed form. A gas will always try to fill as great a volume as possible, and will therefore fill the room, the tank and so on, where the gas is stored. The cohesion force in gas is too small to prevent the molecules from changing both the distance and the position in accordance with each other. The expansion force gets free scope and the gas expansion is total and unlimited. By exposing gas to forces greater than the expansive force itself, the gas will be compressed.

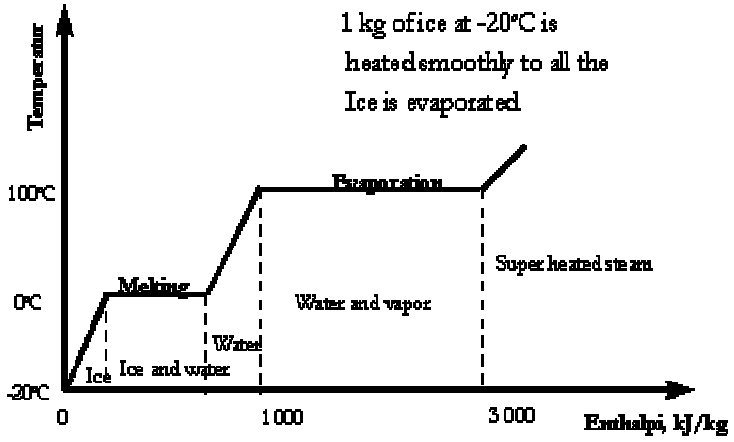
5.5.6 Phase changes



Any substance can be transformed from one condition to another, by means of temperature changes or varying temperatures and pressure. Ice, water and water vapour are the same substance in different forms. The transformation between cohesion and expansion with water molecules goes through these three phases - solid substances, liquids and gases.

5.5.7 Melting

When a solid, pure crystal substance is continuously supplied with heat, the substance will melt. For example:



1 kg of ice with a temperature of -20°C exposed to heat (the pressure is 1 atm). A thermometer placed in the ice will show a rise in temperature up to 0°C, which is melting point of the ice. The heat supplied after the melting point is achieved will have no effect to any temperature rising, as long as the ice is present.

During the melting, the temperature is invariable, and the heat supplied during the melting process is consumed in melting the ice. When all the ice is melted, the temperature in the water will rise. So, the amount of heat supplied to 1 kg of the

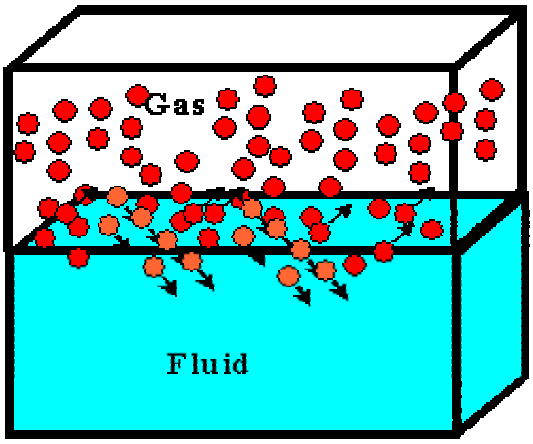
solid substance, in order to reach the melting point where the change from solid to liquid form occurs, is called the "melting heat".
The heat needed to transform a solid substance at a given temperature, into a liquid substance with the same temperature, is called the "specific melting heat". The unit for specific melting heat is Joule/kg.
The heat necessary to evaporate one kilo of a certain liquid substance is called "specific melting heat", abbreviated "r". The unit for specific evaporation heat is J/k.

5.5.8 Enthalpy

A substance's total energy consists of the external energy (work) plus the internal energy. Enthalpy is an expression for a substance's internal energy abbreviated "h". This enthalpy is an expression of how much energy is tied up in one kilo of the substance. The unit for enthalpy is Joule/kg. The comparison of enthalpy to temperature change of gradients shows how much energy is needed to be supplied to bring ice through the three different stages.

5.5.9 Evaporation

A liquid change to gas is called evaporation. This may happen by evaporation or boiling. To achieve evaporation, heat of evaporation is needed. Some liquids evaporate very quickly, such as gasoline and ether. Other liquid substances evaporate very slowly, such as in crude oil. Evaporation is vapour formed out of the liquid surface and occurs at all temperatures.
This is explained by some of the liquid's surface molecules being sent into the air, which is strongest at high temperatures, dry air and fresh wind. The specific temperature calls the amount of heat needed for one kilo of liquid with fixed temperature to form into one kilo of steam with the same temperature". The heat from evaporation is set free when the steam forms to liquid again, or condenses.
The heat necessary to evaporate one kilo of a certain liquid is called "specific heat of evaporation", abbreviated as (r). The unit for specific heat of evaporation is J/kg.



5.5.10 Boiling

Boiling is steam formed internally in the liquid. The boiling occurs at a certain temperature, called "the boiling point". Water is heated in normal atmospheric pressure (1 atm), in an open container. In common, some parts of air are always

dissolved. The rise in temperature is read from a thermometer placed in the liquid's surface. When the temperature has reached 100°C, steam bubbles will form inside the liquid substance, especially in the bottom of the container. With continuous heat supply, the bubbling will rise like a stream towards the surface and further up into the air. The water is boiling.
The formation of bubbling steam can be explained as follows:
During the heating, the water molecule's kinetic energy increases, consequently the molecules demand more space. During the boiling, as long as there is water in the container, the temperature will be 100°C.
The boiling point is dependent upon the pressure. If the steam or the atmospheric pressure increases above liquid substance, the boiling point will also rise. If the surface temperature is just below the boiling temperature, then the water steam will evaporate on the surface. The evaporation point and the boiling point will be the same accordingly.
The pressure from the surrounding liquid is the total amount of pressure above the liquid, Pa, plus the static liquid pressure.

$P = Pa + (\rho \times g \times h)$

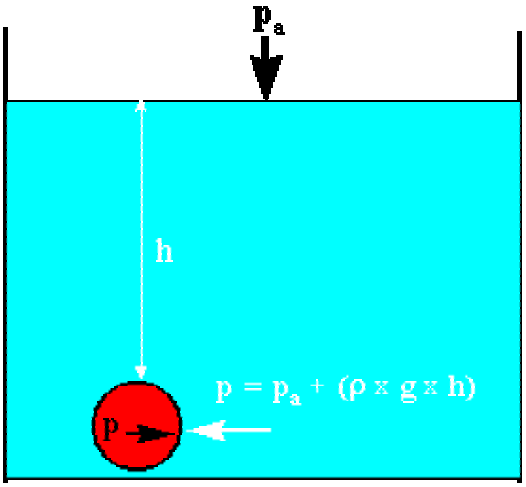
P = pressure in Pascal (100 000 Pa + 1 bar)

Pa = barometer pressure

ρ = the liquid density in kg/m^3

g = force of gravity acceleration ($9{,}81 m/s^2$)

h = liquid column in meter.



When reducing the pressure above the liquid, the boiling point will also be reduced. A practical use of this characteristic is the production of fresh water on board (fresh water generator).

5.5.11 Condensation

Condensation is the opposite of evaporation. If a gas is to be changed to liquid at the same temperature, we must remove the heat of evaporation from the gas. A gas can be condensed at all temperatures below the critical temperature. By cooling a gas, the molecule speed decreases hence the kinetic speed. The internal energy decreases, as well as, the molecule units and liquid forms.

5.5.12 Distillation

Distillation is a transferring of liquid to vapour, hence the following condensing of vapour to liquid. Substances, which were dissolved in the liquid, will remain as solid substance. With distillation it is possible to separate what has been dissolved from the substance which was being dissolved. When a mixture of two liquids with different boiling point is heated, will the most volatile liquid evaporate first while the remaining becomes richer on the less volatile? On board, for instance, seawater is distillated by use of an evaporator.

5.5.13 Saturated, Unsaturated or Superheated Steam

Let us imagine boiling water, releasing vapour from a container, leading the steam into a cylinder that is equipped with a tightening piston, a manometer and two valves. The steam flows through the cylinder and passes the valves, whereon the valves are closing. There now is a limited and fixed volume of steam in the cylinder. Around this cylinder a heating element is fitted. Vapour from the container is constantly sent through this heating element to ensure that the temperature is maintained constant.

The piston is pressed inwards, and now the manometer should show a rise in pressure. But, the manometer shows an unchanged pressure regardless how much the volume is reduced. What's happening is, the further the piston is pressed inwards, some parts of the steam is condensed more using less volume. The vapour from the heating element removes the condensed heat, which is liberated during the condensation process.
We find that the amount of steam, which is possible to contain per volume unit, remains constant when the steam's temperature is equal to the condensation point at the set pressure. The room cannot absorb more vapour, it is saturated with steam and called "saturated". If the piston is pressed outwards, the pressure will still show constant. The conclusion is:

- **With temperature equal to the condensation point by set pressure, steam is saturated.**
- **Steam above boiling water is saturated.**
- **Saturated steam with a set temperature has a set pressure. This is called saturation pressure.**
- **With constant temperature saturated steam cannot be compressed.**

This also concerns vapour as saturated steam of other gases. Using the same cylinder arrangement as before.
The cylinder contains saturated steam, no water. The piston is drawn outward. When no water exists over the piston no new steam will be supplied underneath. The manometer will now show reduced (falling) pressure as the steam expands. When saturated steam expands without supplying new steam, it is called unsaturated steam. The room has capacity to collect more steam.

5.5.14 **Unsaturated steam** contains lower pressure than saturated steam at the same temperature. The unsaturated steam in the cylinder can be made saturated again in two ways. Either by pushing the piston inward to the originated position, or let the unsaturated steam be sufficiently cooled down. When the temperature is reduced, the saturation pressure will reduce. Unsaturated steam will, in other words, have a too high temperature to be saturated with the temperature it originally had. Therefore, this often is referred to as superheated steam.

5.6 THE GAS LAWS

The gas laws are laws that describe the basic facts for ideal gases. Many actual gases under pressure and temperature that we normally get in touch with can not observe as ideal gases. Calculations based one-sided of the gas laws, will therefore necessarily often depart from reality.
The gas laws are meanwhile important by that the laws establish simple and clear connections by the condition changes of the gases.

5.6.1 The Boyles law

Boyles law, of Mariottes law establish that when the gas quantity is confined and the volume varies under constant pressure, the pressure will vary so that the product of pressure and volume is constant. The law can also express as:

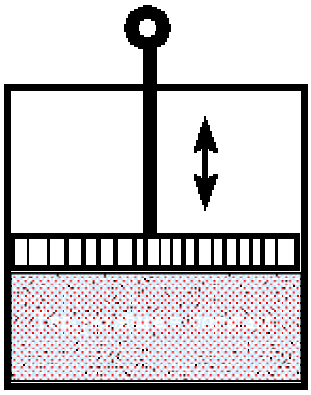
$p \times V = \text{constant}$

One illustrate the law a by thinking a cylinder filled with gas. A well-adjusted piston closes the gas inside the cylinder.

The pressure in the gas is p, by a volume V, before changing. If the piston is removed so that the volume alters to V, the pressure p after volume change is:

$$\mathbf{p_1 \times V_1 = p_2 \times V_2}$$

$$\mathbf{p_2 = (p_1 \times V_1) / V_2}$$



A change of state in the gas where the temperature is constant is called an **isotherm** alteration.

The Boyles law agrees to good approach for air and hydrogen up to about 100 pressures of the atmosphere. For other gases as carbon dioxide, the law is only for lower pressure.
If the pressure is 1 bar and the volume 1 litre before alteration, after reducing the volume to half, the pressure will be:

$p_2 = (p_1 \times V_1) / V_2 = (1 \times 1) / 0{,}5 =$ <u>2 bar</u>

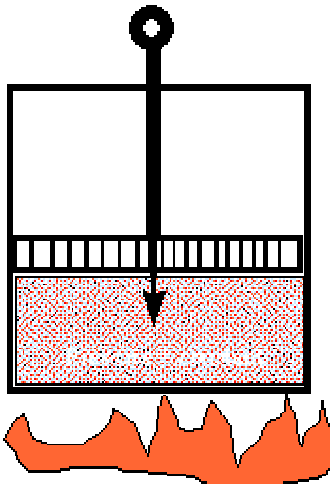
5.6.2 Gay-Lussacs laws

Gay-Lussacs 1.law establish that the gas volume varies proportionally in condition to the absolute temperature of the gas when the pressure is constant. The law can also express as:

$V_1 / T_1 = \text{constant}$

The law can illustrate by thinking a cylinder filled with gas. A good adjusted piston that moves free shuts the gas inside the cylinder.
The pressure in the gas is constant and determined by the weight of the piston. If you heat the gas so that the temperature alters from T1 to T2, the volume alters from V1 to V2. The new volume is:

$V_1 / T_1 = V_2 / T_2$
$V_2 = (V_1 \times T_2) / T_1$



An alteration of state in the gas under constant pressure is called an **isobar change.**

Gay-Lussacs 2.law establish that the pressure of a gas quantity is proportional to the absolute temperature of the gas when the volume is constant. The law can also express as:

$$p_1 / T_1 = \text{constant}$$

One can illustrate the law by thinking a cylinder filled with water. The piston is locked so that the volume stays the same.
If you heat the gas so that the temperature is altered from T1 to T2, the pressure will alter from p1 to p2. The new pressure after heating will be:

$$p_1 / T_1 = p_2 / T_2$$

$$p_2 = (p_1 \times T_2) / T_1$$

A state of proportion in the gas with unaltered volume is called an **isochor** alteration.

5.6.3 The absolute zero point.

Gay-Lussacs experiment is used to decide the absolute zero point. If you heat a small glass tube in water where a small mercury droplet fences an air column, the state between the air volume and the temperature is plotted in a diagram when the temperature changes.

When the temperature rises, the volume increases. The read off values for temperature and volume is close to a straight line. The differences are so small that they are inside the accuracy. The line that emerges shows how the volume varies with the temperature under constant pressure. The pressure will at all times during the experiment be the total amount of the atmospheric pressure and the weight of the mercury droplet.

The Avogadros law

The Avogadros law says that equal volumes of two gases with the same pressure and temperature contains the same amount of molecules.
A conclusion of this statement is that the state between two gases density (p) at the same pressure and temperature, has to be equal to the state between the masses of the individual molecules in the gases or the state between the relative molecule masses (M).

$$r_1/r_2 = M_1/M_2$$

The Dalton Law

The Dalton law say that the total pressure in a gas mixture is equal to the total amount of the partial pressures (part-pressure), that each of the gases will alone in a room with the same temperature as the mixture. The law expresses as:

$$p_{total} = p_1 + p_2 + \ldots\ldots\ldots\ldots p_n$$

The Dalton law is logical. Every gas fills all the volume, independent of other gas molecules that are present. The molecules itself obtains itself an utmost small part of the volume. Therefore every gas will have a pressure that responds to this.
One can also see the restriction of the law from this explanation. It has no longer any existence when the pressure is so large that the molecules occupy a perceptible part of the volume. It has also no accuracy when the gas molecules has influence on one another, and also not if the gases has a chemical reaction against one another.

The Joules law

The law of Joules say that the inner energy in a precise amount of ideal gas only depend of its temperature and is independent of the volume. If pressure and volume is changed in a process, the inner energy will remain constant if the temperature is constant.
According to the kinetic gas theory, the inner energy in an ideal gas is equal the complete kinetic energy that the molecules have because of its disordered movement. This can express, as the inner energy in a precise amount of ideal gas is proportional with the absolute temperature. A conclusion of this statement is if an ideal gas expand (gets a larger room), the temperature and with that the inner energy will remain unchanged after expansion.
Indirectly, the law is demonstrated by experiments with actual gases. These experiments indicate that the inner energy of an actual gas is dependent of the gas volume, but this dependence decreases the more the gas approach to become an ideal gas. In an actual gas the force of attraction works between the molecules. The force of attraction between the molecules by usual pressure is small, but is not equal zero. It is therefore necessary to perform work to increase the distance between the molecules and expand the gas volume. If the expansion is adiabatic, that is without heat exchange between the surroundings. This work can only be because in expense of the molecule kinetic energy and the temperature of the gas sink.

Joules-Thompson effect

The Joules-Thompson effect describes the divergence from the Joules law of an actual gas. According to Joules law, the temperature will not change if a gas expand freely without working.
Practical the temperature will fall freely for most gases of hydrogen and helium that is heated during expansion. When air expand from about 50 bar to the atmospheric pressure, this is cooled with about 13K. It is the result of this effect one can observe or feel when air or another gas is let out from an air bottle and the delivery valve (expansion valve) is noticeable colder.
Cooling plants that are used on board expand the vaporisation of the gas. The Joules-Thompson effect in such plants is insignificance and therefor not calculated with.

Diffusion

Bromic gas that has a brown colour is well suited to demonstrate diffusion between gases. If you fill a glass with bromic gas and a glass filled only with air on top, one can after a while se that the content in both glasses is gradually brown-coloured. Diffusion has taken place. In despite of that bromic gas has five times as large density as air diffuses that gas up in the top glass with air.
All gases can mix at diffusion. As the molecules in the gases are accidental and unorganised, a precise gas molecule will over time come any where in the room that is available (according to the kinetic gas theory). From the kinetic gas theory it is natural to draw the conclusion that the diffusion velocity is faster the larger velocity the molecules have. At experimental experiments the Englishman Graham reached following connections:
The diffusion velocity for a gas is converted with the square root of the density of the gas and directly proportional to the square root of the absolute temperature.
These can mathematical express as:

$$\mathbf{v_1/v_2 = \sqrt{r_2}/\sqrt{r_1}}$$

As equal volume of two gases contain, at the same pressure and temperature, that same amount of molecules (Avogadros law), the state between the density of the gases (p) and the masses of the individual molecules and the relative molecule masses (M) be:

$$\mathbf{r_1/r_2 = M_1/M_2}$$

From above mentioned two expressions, gases diffusion velocity can express as:

$$\mathbf{v_1/v_2 = \sqrt{M_2}/\sqrt{M_1}}$$

This formula can be used to find how fast gases diffuse in proportion to one another. When the molecule mass to nitrogen is 28 and the molecule mass to hydrogen er 2, we find the relative diffusion velocity for nitrogen to:

$$\mathbf{v_1/v_2 = \sqrt{M_2}/\sqrt{M_1} = \sqrt{32}/\sqrt{2} = 4}$$

that shows that hydrogen diffuse 4 times faster than nitrogen.

BASIC REFRIGERATION

There is seven different principals for cooling, but we are to concentrate about the process that has been known the longest and that has the largest distribution.

The process of evaporation is the process that is used at the most in modern cooling technique. It is here the cooling medium evaporation heat that is utilised to transfer heat from one place to another. For a liquid to evaporate one must supply heat to the liquid. The heat is taken from the surroundings that thereby are cooled. In an air condition plant on board, Freon liquid is lead into an evaporator, the heat from the air is transferred to the liquid that evaporate, and the air is cooled.
One must here emphasise that there is always in speak of transport of heat from a warmer media to a relative colder media. Equal that water flows from a higher level to a lower because of that the gravity will heat from a higher temperature to a lower. How can then heat transfer from the relative cold Freon gas that is sucked back to the compressor and transfer to the relative much warmer seawater?
To elevate water from a lower to a higher level, work has to be done (by help of a pump) of the water. To transport heat from a lower temperature to a higher or likewise.

The thermodynamics 2nd main sentence say:

"Heat can only be transported from a body with low temperature to a body with higher temperature by converting of mechanical work."

It is this law that is utilised in any cooling plants or condensation plant for cargo on gas ships. Heat is transferred from the relative cold cargo gas to the relative much warmer seawater. For this to be possible one must perform a work on the gas by the compressor compressing the gas to a higher pressure and temperature than the seawater; and heat can thereby transfer from the gas to the seawater in a heat exchanger. Since the compressor secures a continuous high pressure and temperature in the heat exchanger, both the supplied heat quantity under compression and the evaporation heat transfer to the seawater. The gas condenses and is allowed back by a regulation valve and back into the tank.
The job of the regulation valve is to secure a liquid lock for thereby to maintain a high pressure in the condenser, and to distinguish between the low-pressure side and the high-pressure side in a condensation plant. Without this valve it is impossible to maintain the condensation pressure and keep the cooling process up. In many cooling plants thermostatic expansion valves are used at this purpose. A thermostatic expansion valve is not regulated by the liquid level in a liquid collector before the valve, but by the overheating temperature inside the evaporator. Regardless of the valve is a regulation valve or a thermostatic expansion valve, the job is the same and the valve has no "cooling technical" qualifications in itself. (ref. Joules-Thompson effect).
On ships that transport condensed gases in bulk, the cargo in the cargo tanks will at all times be in its boiling point. As the temperature difference between the cargo and

the surroundings are partly very large, heat will transfer from the surroundings to the cargo. Isolation will never prevent heat-transfer, only reducing this.

The heat to the cargo will lead to temperature increase with thereby following pressure increase. This process will unprevented be in progress until the temperature of the cargo is equal as the surrounding temperature. If the cargo is propylene and the surroundings ambient temperature is 27^{o}C, the pressure in the cargo tank will gradually build up to about 11 bar. With exception of fully pressurised gas carriers, there is no gas ship with cargo tanks that is constructed to resist such a pressure.
To maintain the tank pressure less than the pressure the cargo tanks is designed for (MARVS), it is necessary to remove the supplied heat. This can be done in three different ways. We can condensate the vapour back to the cargo tank, we can use the vapour as fuel or we can blow the vapour out in the atmosphere. LNG ships use the vapour in the propulsion machinery and that is a part of the chart.
How the cooling plant is constructed depends of the size of the ship and what kinds of cargo the ship is built to carry. Roughly the cargo cooling plant is divided into in three main types:

- Direct cooling plants; the cargo condensing directly against seawater.
- Cascade plants; the cargo gas is condensing at a cooling media as for example R22
- Indirectly cooling plants; the cargo is cooled or condensed against a cooling media or a without compression of the cargo gas.

As mentioned earlier, there is unqualified necessary to cool a compressed gas under its critical temperature to condensing this. As the condensing temperature normally is no lower than 5^{o}C above the seawater temperature, we can set a cool technical limit for what can be condensed against seawater.

The diagram shows a saturation curve and the critical point for the most actual gas cargo. It is here drawn a reflected boundary line at a condensing temperature of 37^{o}C. We then suppose that the seawater temperature in the area the ship is trading will be maximum 32^{o}C and that the highest condensing temperature thereby is 37^{o}C.

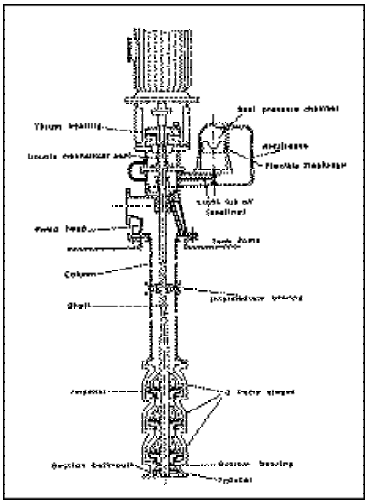
06- Cargo Handling Equipment

6 CARGO HANDLING EQUIPMENT

Centrifugal pumps are utilised as main unloading pumps on gas tankers. The unloading pumps are located down in the cargo tank's swamp or as close to the tank bottom as possible. This is because the centrifugal pumps do not suck, and are thereby dependent upon good drainage. The pumps are either the deepwell pump type, submerged type or booster pump. Normally, the number of revolutions on deepwell and submerged pumps lie on 1300 – 1800 RPM. Pumps driven with hydraulics have the advantage that the number of revolutions can be adjusted. Electrically driven pumps normally have a stated number of revolutions, but lately they are delivered with a variable number of revolutions, for example 1370/800 RPM. Booster pumps normally have revolutions from 3500 – 4000 RPM. It is very important to follow the user manual supplied by the pump manufacturer to ensure what to do before we start a pump, and what routines to follow at overhaul and inspection of the pumps.

6.1 DEEPWELL PUMP

Deepwell pump is the pump type that is often used on gas tankers. Deepwell pumps are pumps with a long shaft between the driving motor and the pump. The shaft goes inside the tank's discharge pipe from the pump up to the tank dome. The discharge pipe is a solid pipe that goes up through the tank and out to the flange on the tank dome to the liquid line. The discharge pipe is constructed with several lengths with pipes, and there is a shaft bearing on each flange. The bearings are lubricated and cooled down by the liquid that is pumped from the tank. It is very important not to run the pump without liquid. This may result in damage of bearings and then the shaft.
The motor that drives the pump is either electric or hydraulic. There is a mechanical sealing device between the motor and the discharge pipe in the cargo tank. When using the pump, we must have at least one bar higher pressure on top of the mechanical seal than we have in the tank. It is important to closely read the pump's user manual about the routines before discharging, because the routines vary some from different manufacturer.

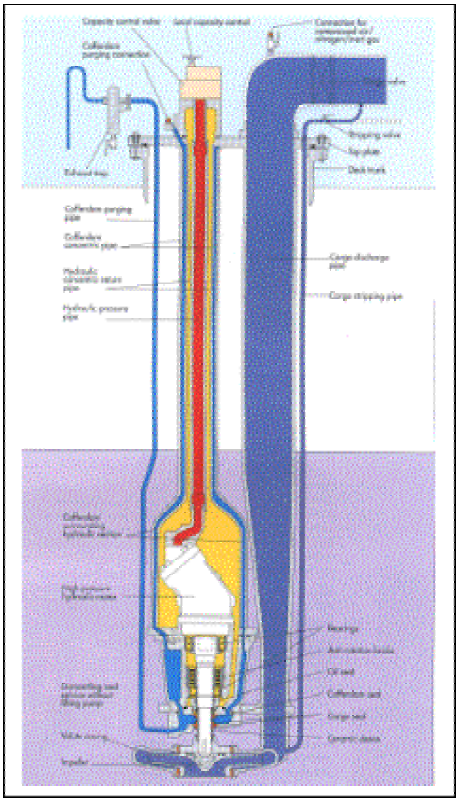


6.1.1 Submerged pump

Submerged pumps are multistage centrifugal pumps that are often used as discharge pumps on large LNG and LPG tankers. The motor and pump are submerged down in the tank sump or as close to the tank bottom as possible. The motor is connected directly to the pump with a short shaft on this type of pump. The liquid that is pumped lubricates and cools the pump's bearings. It is therefore essential that the pump is used only when there is liquid in the tank. The liquid is pumped up through the tank's discharge pipe and up to the liquid line.

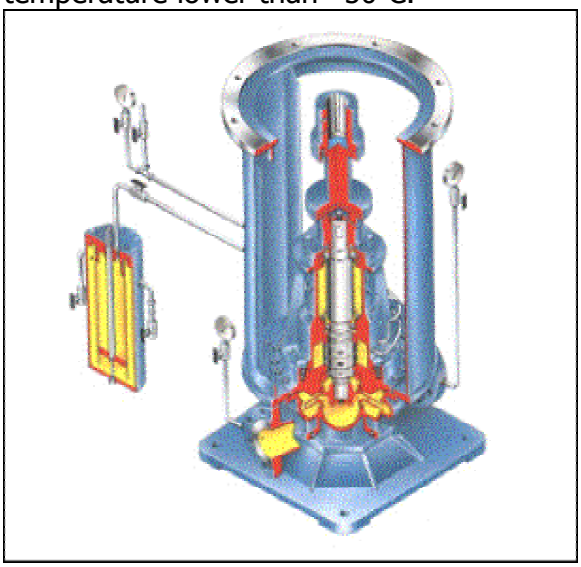
This type of pump is equipped with electrical motor. The cables to the electric motor are either made of copper or stainless steel. If copper is used in the cable, the cables must be sheathed with stainless steel to prevent damage on the cable from corrosive cargoes. When transporting Ammonia, the cable and engine must be sheathed with a thin layer of stainless steel. It is important that the stainless steel sheathing is kept unbroken, and we must avoid a sharp bend on the cable to protect the stainless steel sheath. One must at all times check the resistance of the cable insulation before starting the pump.

Submerged pumps are also installed as portable pumps. The discharge pipe is then the steering pipe for the pump. At the bottom of the discharge pipe it is a non-return valve that opens when pump is lowered and shut when the pump is taken up. Before opening the discharge pipe it must be gas freed, this is done either with inert gas or Nitrogen.



6.1.2 Booster pumps

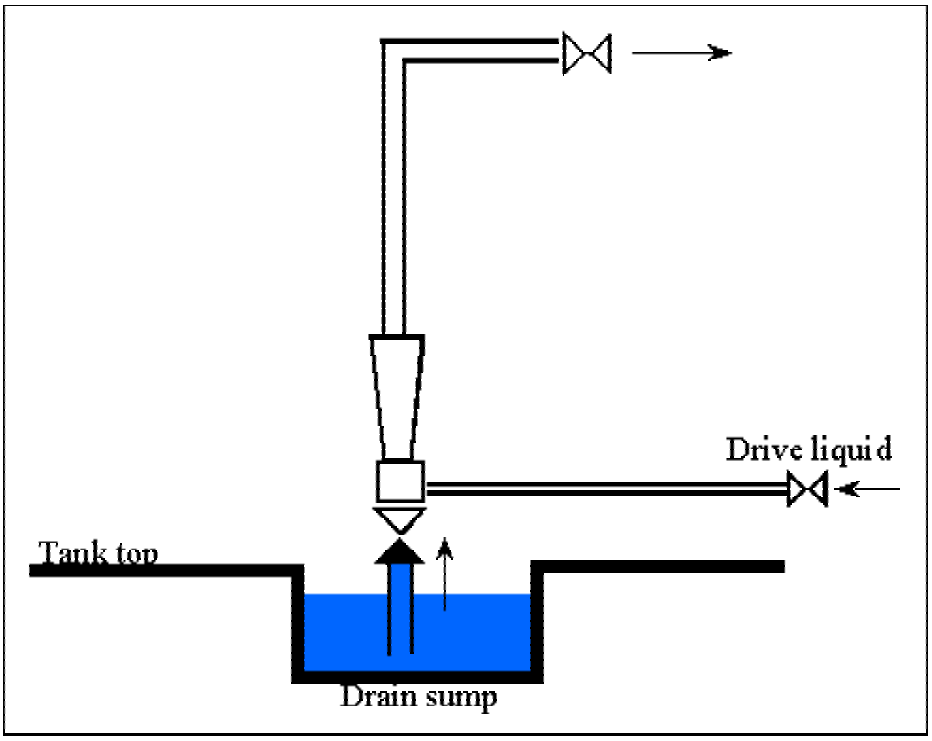
Booster pumps mentioned here are auxiliary pumps for cargo handling. The pump is one-staged centrifugal pump and is often installed on deck near the pipe manifold. The booster pumps on gas tankers are used either as a main discharge pump, auxiliary discharge pump, deck tank supply pump or heater feed pump.
The booster pumps are driven with electric or hydraulic motor. The engine and the pump are connected together with a short shaft with coupling in
between. It is very important that the motor and the pump are aligned according to the manufacturer manual, and the clearances specified inside are followed.
Booster pumps that are regularly utilised should, as a good rule, be turned by hand once a week to prevent destruction of the motor and pump bearings. It is important that the booster pumps are blended off on LPG/LEG tankers when carrying cargo with lower temperature than –50°C. Booster pumps are rarely designed for temperature lower than –50°C.



6.1.3 6.1.3 Hold spaces and inter barrier spaces

In hold space and inter barrier space there is requirement of drainage system separated from the machinery drain system. The drain system could be submerged pumps, deepwell pumps or ejectors. These pumps can be used to drain water or cargo spill from the bilge.
Generally, there are spool pieces (short pipe pieces) that are produced especially for each hold space and on each side and fit both to the cargo system and the seawater system. It is important that the spool pieces are disconnected, and the flanges are blinded off when the bilge system is not in use.

Example of ejector in hold space



6.2 LOADING LINES, PIPES AND VALVES

6.2.1 Loading lines and pipes

The loading lines and pipes mentioned here refer to gas carrier's cargo handling system. This involves liquid lines, vapour lines, condensate return lines, lines to vent mast, pipes inside the cargo tank and seawater pipes to the cargo cooling plant.

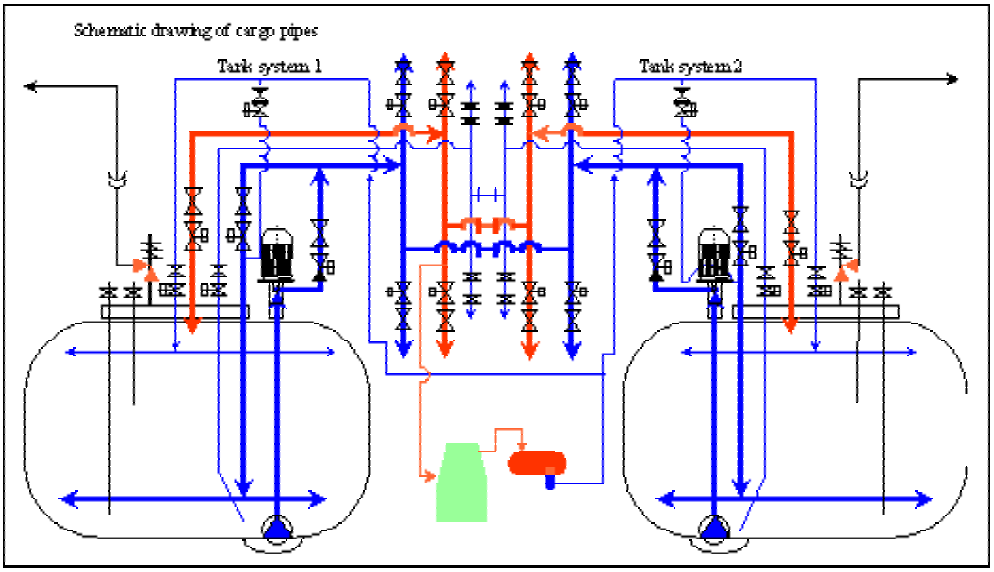
All loading lines on gas carrier: liquid lines, gas lines and lines to vent mast have the same requirements as pressure vessels regarding of temperature and pressure they are meant to handle. All welding on pipes exceeding 75 mm in diameter and 10 mm wall thickness or more must be X-rayed and classed by the class company. The same regulation do we have on flanges and spool pieces also.

All loading lines outside the cargo tank must be produced by material with melting point no less than 925°C. The loading lines on gas carriers are mostly produced of stainless steel, but low temperature nickel steel is also in use. All loading lines with an outside diameter of 25 mm or more must be flanged or welded. Otherwise, lines with an outside diameter less than 25 mm can be connected with treads.

Loading lines designed for cargo with low temperature, less than –10°C must be insulated from the ship hull. This to prevent the ship hull to be cooled down to below design temperature. The hull has to be protected against cold cargo spill under spool pieces and valves on all liquid lines. This is done with wood planks or plywood. To prevent cold cargo spill on the hull plates, a drip tray must be placed under the manifold flanges.

All lines that are thermally insulated from the hull must be electrically bonded to the hull with steel wire or steel bands. On each flange on lines and pipes where gaskets is used, there must be electrical bonding with steel wire or steel band from flange to flange.

On all cargo lines where it can be liquid it is required with safety valve. Vapour from the safety valve outlet must go back to the cargo tank or to the vent mast. If the return goes to vent mast the pipe must be equipped with a liquid collector to prevent liquid to the vent mast. The safety valve's set point is dependent upon the pressure for which the line is designed. The safety valves must be tested and sealed by the ship Class Company.



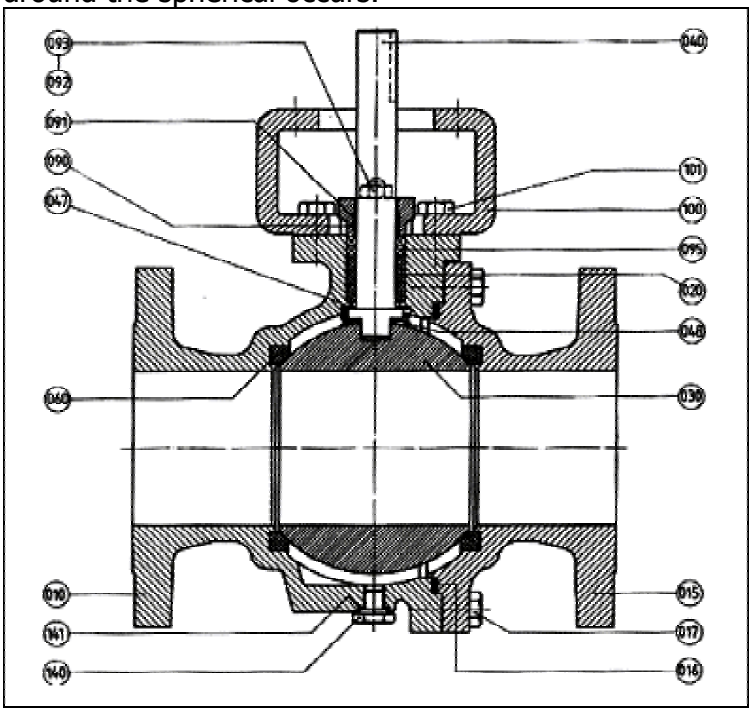
6.2.2 Valves

The most common valves used on the cargo handling equipment on gas carriers are ball valves, butterfly valves and seat valves. All valves used on cargo lines have to be installed with flanges, and the valves must be electrically bonded to the line either with steel wire or steel bands.

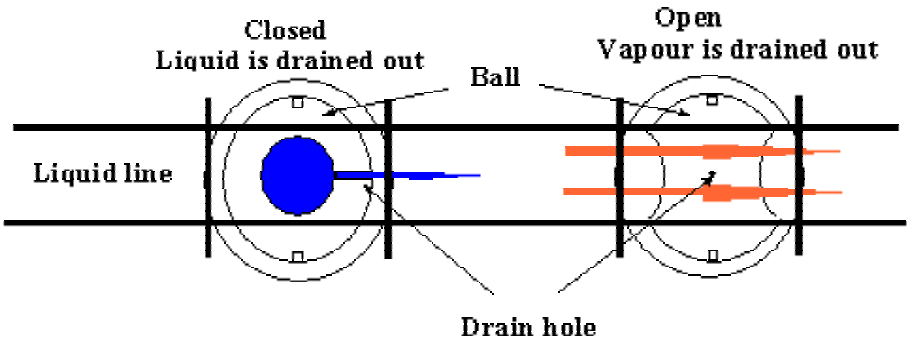
6.2.3 Ball valves

On semi and fully refrigerated gas carrier's ball valves are often used on the cargo lines and cargo cooling plant. The ball valves tolerate high pressure and large thermal variations, and they are also approved for chemicals. The valve seats and sealing devices are produced in Teflon, the ball and spindle is produced in stainless steel. The ball valve principle function is the pressure on one side of the ball forces the ball against the seat and the valve is closed. If the pressure is equal on both sides of the valve, leakage may occur.
On some types of ball valves the ball is fastened to the spindle, other types of ball valves have floating ball. With a floating ball the pressure is equal all around the ball, and the ball is pressed even toward the seat. With the ball fasten to the spindle it is pressed aslant towards the seat and the valve seat can be damaged and the valve will leak.

Frequently, particles are left between the valve ball and the valve house, and these particles can easily cause damage to the valve seat and the ball. The valves must from time to time be opened and the ball and seat have to be cleaned especially the manifold valves. There is a drain hole on the ball itself. It is of importance to ensure that when the valve is closed, the drain hole pointing where it is least natural pressure, then the liquid inside the ball can be drained or boiled off. This prevents large pressure inside the ball, liquid expansion and wreckage of the sealing devices around the spherical occurs.



Sketch of operation of drainage hull:



Advantages:

Ball valves tolerate large pressure and thermal variations due to the shape of the ball. Tolerates both gases and chemicals. Easy to maintain and overhaul.

Disadvantages:
The valves are expensive, and have costly spare parts. They can be difficult to shut at temperatures down to –90°C and colder (this can be relieved by adding a thin packer between the to parts of the valve house). Ball valves are unfavourable as regulation valves, as it is difficult to adjust to low flow through the valve.

6.2.4 Butterfly valves

Butterfly valves are often used on the seawater line on gas carriers, such as water to heat exchanger (cargo heater), seawater condenser, oil cooler, the compressors etc. Butterfly valves are also often used on lines with large diameter as cargo lines, where there is not such a large pressure or thermal difference. Butterfly valves should be moved at regular intervals to prevent the seat from fastening and be damaged and cause leakage valve.

Advantages:
This type of valves has more reasonable price than ball valves. They have lower weight than ball valves to corresponding pipe diameters. They are better than ball valves for regulation of flow.

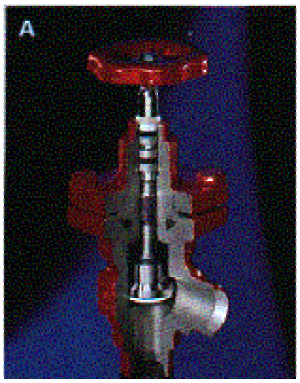
Disadvantages:
They are exposed to cavitation damage on the valve seat and flap when too high liquid flow through the valve. They are less suitable at low temperatures than ball valves.

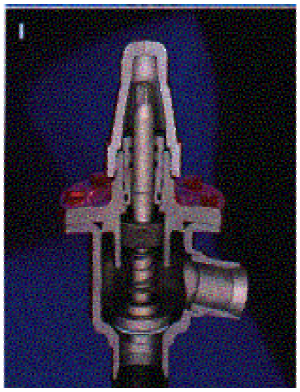
Seat valves

Seat valves are frequently used as one-way valves (check valves) on loading lines, as the pressure valve on the discharging pump, on condensate return lines back to the

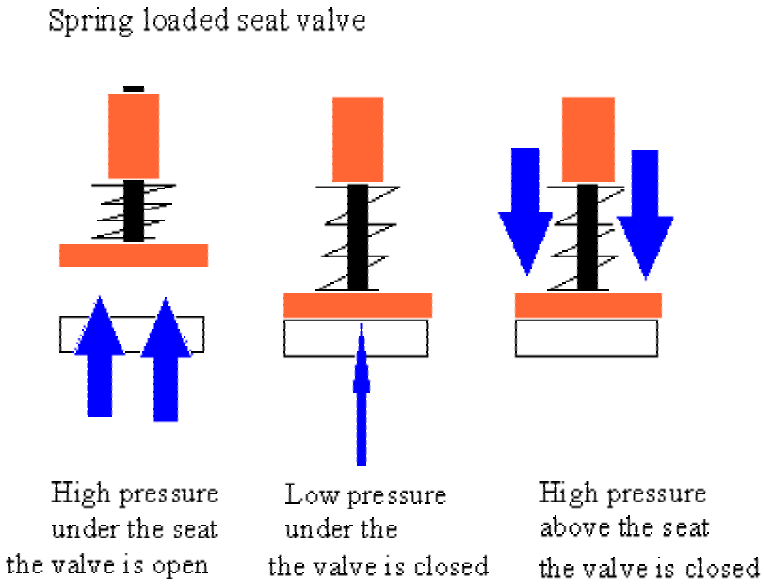
cargo tank and on the inert gas lines. Seat valves are opening by turn the spindle anti clockwise and the valve seat can wander freely on the spindle. When the pressure increases in the line under the valve seat, the seat is lifted up and the valve is open. When the pressure ceases under the valve seat or the pressure increases above the valve seat, the valve seat will drop down and shut the valve. Opening or choking the valve regulates the amount of flow through the valve.

Example on seat valves:





Sketch on spring-loaded seal valve:


Spring loaded seat valve
High pressure under the seat the valve is open
Low pressure under the the valve is closed
High pressure above the seat the valve is closed

Seat valves that are used as check valves, must be overhauled at regular intervals, and especially the seat and contact faces must be polished/grounded as they are expelled for mark and wear and tear when the valve operates often. The seat valves must also be moved regularly when they are not in use for a long period of time.

Advantages:
The seal valves are reliable and simple to operate. Have large range of utilisation. Have few wearing parts. Reasonable to maintain.

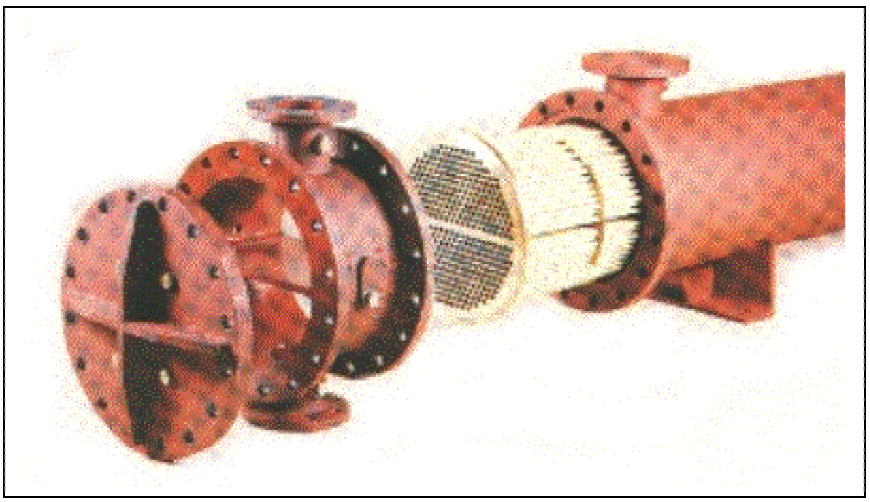
Disadvantages:
Require strict inspection. Start leaking if wrongly operated.

Needle valves

Needle valves are used for regulation of cargo cooling plants, both air regulation and for regulation of Freon in cascade cooling plants. The needle valve is the valve type that empirically is best suited for regulation of low flow volume.

HEAT EXCHANGER

Heat exchangers are utilised in several different parts of cargo handling on gas carriers, as heat exchangers (cargo heater), condensers for cargo cooling plant, vapour risers, super heaters and oil coolers for compressors. In most of the heat exchangers seawater is used as the medium on gas carriers, which the products are cooled or heated against.



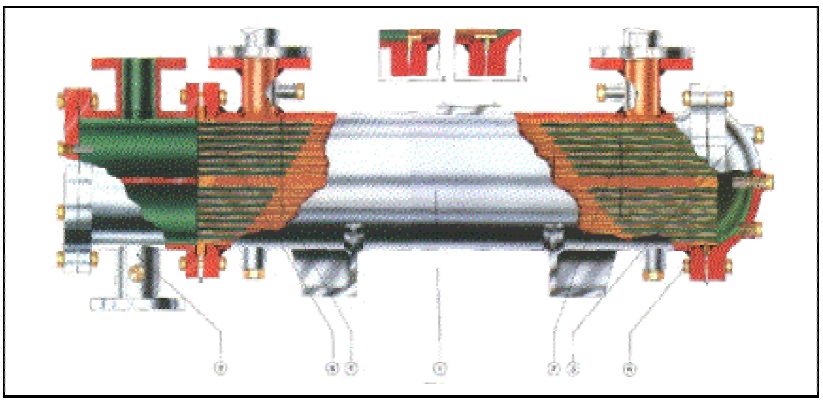
The heat exchangers that are used for cargo handling must be designed and tested to tolerate the products the gas carrier is certified for. Heat exchangers that are used for cargo handling are considered as pressure vessels, and IMO requires one safety valve if the pressure vessel is less than 20 m^3 and two safety valves if it is above 20 m^3. All heat exchangers that are used for cargo handling must be pressure tested and certified by the gas carriers Class Company.

Heat exchangers where water is used as the medium and are utilised for heating have little or no effect with water temperature less than 10^oC. Seawater became ice at about 0^oC and starts to free out salt at about 50^oC. So with operating

temperatures with a larger variation than from 10°C to 45°C, one ought to use another cooling medium than seawater. Some terminals do not accept water as medium in heat exchangers, therefore one must either heat the cargo on route at sea or the gas carrier must have heat exchangers that do not use water as medium.
It is of importance to ensure that the water out of a heat exchanger is never below 5°C. These prevent the water in the heat exchanger from freezing and eventually damage the heat exchanger.

Tube heat exchangers

Tube heat exchangers are produced with tube bundles either as straightened pipes or u-formed pipes placed into a chamber. The pipes in the tube bundle have an inside diameter on 10 to 20 millimetres. There is a cover installed on each end of the chamber to clean the pipes more easily and maintain these. It is, at all times, important to ensure that the velocity of the liquid that is being pumped through the heat exchanger is not too high, to prevent cavity damage in the tube bundle or the end covers.



The tube bundle is made of stainless steel, carbon steel, copper-nickel alloy, aluminium-brass alloy or titan.
Which choice of material one decides to choose, depends on the product one will operate and the costs associated with the investment and maintenance.
In tube heat exchangers, where seawater is used as medium, the product to be heated goes in the tube bundle. This prevents remaining seawater from freezing or prevents

remnants of salt deposits inside the tubes. Tube heat exchangers must at regular intervals be cleaned to prevent particles from settling inside the tubes in the tube bundle or in the end covers. One must closely check for cavity damage when cleaning the heat exchanger. Ensure that the gasket is produced in a quality that tolerates the products and temperature one operates it with. Also, ensure that the gasket is correctly placed.